FIRE ENGINEERING DESIGN PROBLEMS

AT

BUILDING CONSENT STAGE

BY

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A research project report presented as partial fulfillment
of the requirements for the degree of
Master of Engineering in Fire Engineering

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ABSTRACT

This project describes many aspects of the submission and review of fire engineering design reports necessary to comply with the Building Act 1991 and New Zealand Building Code 1992 at the building consent application stage. The current common problems in fire engineering are highlighted in this discussion to bring awareness to fire safety designers.

The purposes are to stimulate, provoke and challenge people who are committed to the fire and safety engineering of today so that improvement can be made in their submittal of the fire and egress reports for building consent application.

ACKNOWLEDGMENTS

I want to give thanks to my Lord Jesus for His provision to enable me to complete this report. During the last few months of writing this report, I was sailing through stormy seas. I faithfully held on to the anchor of His love and He sustained me. I also want to apologize to my wife and my children for being a part time husband and father during the last four years.

I wish to express my gratitude to Manukau Consultants Ltd (presently GHD) for giving me the financial support and to my manager Mr. L. Ling for believing in me. I also want to thank the manager of the Building and Resource Services Mr. Kevin Wilkie for keeping me employed, and the team leader Mr. Eric Potts for being a very caring person.

I wish to thank the University of Canterbury for providing me for the opportunity to further my education. A very big thank you to my supervisor Dr. Andy Buchanan for his perseverance and longsuffering in guiding and encouraging me throughout this period.

Special thanks must also go to the BIG BOSS MAN with a gentle nature, John McGregor of the BIA, who has guided and rescued me as I went through a few crises in reviewing building consents. Many thanks to Tony Gibson of Gibson Consultants and John McGregor for reading and commenting on my report. Thanks to Mark Ranfurly and Trevor Henson for proof- reading my report. Many thanks to my brother in Christ Dr. Norman Lawgun for his support and assistance during the last four years. Dr Peter Richards of the University of Auckland was very helpful in helping me understand some of the theory.

The two very special people I would like to give thanks to are our 'Acceptable Solution' Guru Mr. Latchman, in whom I inherited the technique in dealing with all kinds of fireworks; and to Mr. Ian Godfrey, the best looking man at the Kotuku House, who is always willing to share his technical knowledge with me in relation to problems of fire engineering.

Finally, I am praying for all the above people who have helped me with this project. I pray that God will send them and their families a special blessing.

TABLE OF CONTENTS

NOMENCLATURE

BIA	Building Industry Authority
C2	Means of Escape
C3	Spread of Fire
C4	Structural Stability
AS1	Acceptable Solution
FRR	Fire Resistance Rating
BIC	Building Industry Commissioner
NZBC	New Zealand Building Code
SFPE	Society of Fire Protection Engineer
CCC	Code of Compliance Certificate

Purpose groups

CS or CL	For occupied spaces. CS applies to occupant loads up to 100 and CL to occupant loads exceeding 100.
CM	Spaces for displaying, for selling retail goods, wares or merchandise.
SA	Spaces providing transient accommodation, or where limited assistance or care is provided for principal users.
SC	Spaces in which principal users because of age, mental or physical limitations require special care or treatment.
SD	Spaces in which principal users are restrained or liberties are restricted.
SH	Detached dwelling where people live as a single household or family.

SR	Attached and multi-unit residential dwellings.
WL	Spaces used for working, business or storage- light fire hazard.
WM	Spaces used for working business or storage –medium fire hazard
WD	Spaces used for working business or storage – high fire hazard.

CHAPTER 1 INTRODUCTION

1.0 Introduction

This project sets out to look at the current problems in fire engineering design at the building consent application stage. Investigating how fire and egress designers relate to the Building Act 1991 and the New Zealand Building Code 1992. The author is presently involved in fire and egress design as well as working as the principle reviewer for the territorial authorities in Auckland. Exposure to both 'Acceptable Solution' and 'alternative solutions' has placed the author in an appropriate position to address those issues.

The contents of this project may be controversial to some readers. However, the author strongly believes that no matter what level you are at in the field of fire engineering, if you maintain an open mind, you will learn something practical and useful after reading this project.

1.1 The Objective

The objective of this study is to stimulate awareness of Fire and Egress Engineering by highlighting the problem areas observed from reviewing Fire & Egress reports. This will lead to a better understanding of how to provide compliance with the Building Code and Building Act, both for the Territorial Authorities and the designers.

Inspection during construction, Independent Qualifying Person and Warrant of Fitness are not included in the scope of this project.

Relevant documents relating to the Building Act 1991 and the New Zealand Building Code 1992 will be addressed in order to give the reader a better understanding of the practical application of the codes.

Examples based on selected Fire and Egress Reports of past Building Consent applications will be reviewed to demonstrate and highlight the problem areas. The scope of the study relates largely to the problems arising from interpreting the 'Acceptable Solutions' of the Approved Document. A comparison with the latest released draft copy of the Fire Safety Approved Document Revision in July 1999 is also being made. However, the current basic specific design philosophy by the designers will also be discussed in order to give an overview of problems in fire engineering today.

1.2 Background

It would appear that during the very early history of Auckland, when buildings were built predominantly with wood, fire fighting was carried out by passer-by volunteer citizens by means of a bucket brigade. Stands of five buckets filled with water were not uncommon in those days. Garrison soldiers and sailors of the sailing warships would also volunteer help. Asher Asher's volunteer brigade was operating in the 1850s and was later recognised by the city commissioners.

There were five insurance company brigades in and around the city, but they, in the main, were only interested in protecting insured properties – and even in the 1950s some buildings in Auckland still had the insurance company plates displayed in their buildings (Glen 1974).

From the historical beginning, we can see that the insurance company traditionally influenced fire safety. It emphasized the safeguarding of property rather than life safety. NZS 1900: Chapter 5 'Fire Resisting Construction & Means of Egress' (SANZ 1963), the fire code for the last 30 years before the Building Code, was no exception. As a result, it was thought that the national economy was affected by the high costs associated with high fire rating requirements.

The local bodies used to be the absolute authorities. Each Council would have its own by-laws. The bylaws stated prescriptively how things had to be done. The bylaws were criticized to be historically based, inconsistent and not always rational.
In the late 1970's the New Zealand Government realized that a change was required. After many committees and reviews over a 10-year period, The Building Act 1991 and the New Zealand Building Regulations 1992 were legislated and officially adopted in 1993.

It may be easy to imagine that the New Zealand building control documents as part of a pyramid – from the Building Act at the top to a wide-ranging means of compliance at the base of the pyramid (Warworth 1999).

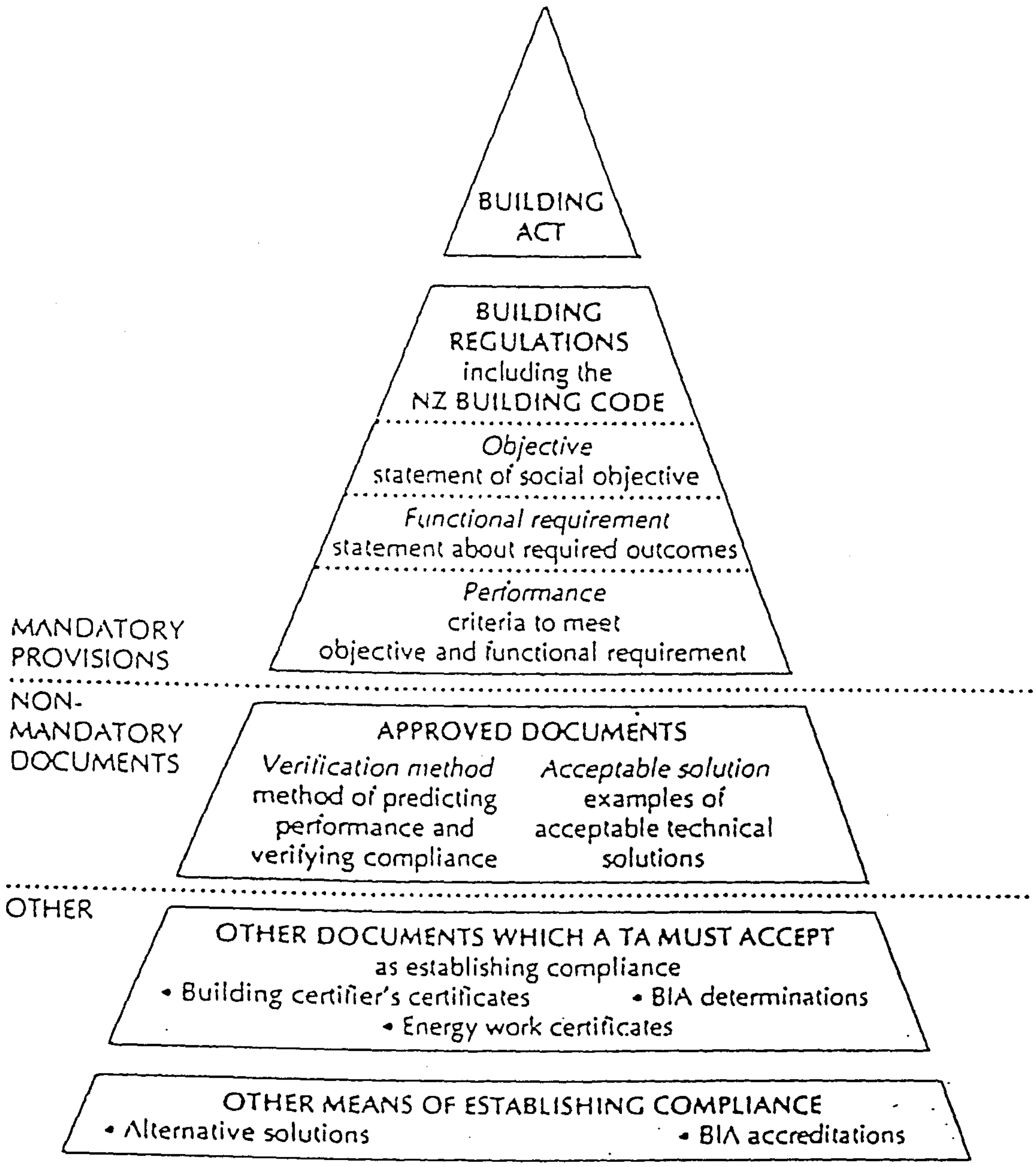


Figure 1.1: The Building Control Document Pyramid

1.3 Legislation

The Building Act 1991 provides a national focus to the building controls, with two objectives:

- The first is to provide for building controls that ensure buildings are safe and sanitary, and have means of escape from fire; and
- Secondly, to co- ordinate these controls with other controls affecting building use and the management of resources.

The Building Act 1991 and the Building Regulations 1992 set down mandatory requirements for buildings which can be achieved in many different ways. This enables flexibility in design solutions rather than restricting how things should be done. This flexibility is facilitated by the performance based New Zealand Building Code, which is the First Schedule of the Building Regulations.

The new direction taken with fire and egress requirements has meant that the model building by law NZS 1900 Chapter 5 (SANZ 1963) has been superseded. The performance based building code has enabled fire and egress designers to be provided with a more comprehensive Fire Safety Approved Document (BIA 1992) based on fire engineering principles.

Seven years have passed since the implementation of the present Fire Safety Approved Document 1992. A new draft of the ' Fire Safety Approved Document Revision' (BIA 1999) was released for public comment in July, 1999. There are many reasons for revising the 1992 document but, in general, they are based on one or more of the following specified by the 'draft' Revision (BIA 1999):

- Experience has indicated a need for more stringent requirements to ensure life safety.

- New knowledge/research has been taken into account allowing obsolete or unjustified requirements to be replaced or revised.

- The previous solution was impossible to comply with, or was not practical.

- The draft solution is more economic and still meets the code intentions.

- The draft solution is more flexible and still meets the code intentions.

- The draft solution is easier for the user to follow and still meets the code intentions.

A comparison will be made between the 'Approved Document' and the 'Fire Safety Approved Document Revision' wherever the clauses in the 'Approved Document' are being mentioned in the examples.

1.4 Design Methods

The performance requirements of the New Zealand Building Code can be achieved in three different ways:

- An approved "Verification Method",
- The "Acceptable Solution" published in the Approved Document 1992,
- An "alternative solution" using specific engineering design.

As for fire and egress requirements, there are

- The Acceptable Solution in the Fire Safety Approved Document 1992,
- The alternative solutions use specific fire engineering design.
- The Verification Method for design (approved calculation method), which only applies to structural aspects of fire engineering because there is no Verification Method for fire. A thorough study of the subject can be obtained from "Structural Design For Fire" (Buchanan 1999).

1.4.1 The Acceptable Solution

The 'Acceptable Solution' is a prescriptive section of the Building Industry Authority (BIA) Approved Documents developed under Section 49 of the Building Act 1991. Current fire protection engineering practice is largely the application of prescriptive requirements, i.e., the engineer designs according to predetermined requirements based on generic occupancies or on class of hazard or risk. Such a prescriptive approach is the norm for 'standard' applications in many engineering disciplines.
The Acceptable Solutions are not mandatory. However, it is the only prescriptive approved method of achieving compliance. Under Section 50 and 89 of the Building

Act, no civil proceedings may be brought against a territorial authority for anything done in good faith in reliance on a document.

1.4.2 The 'Alternative Solutions'

Designs, which depart from the Acceptable Solution, are called 'alternative solutions'. They are performance-based fire safety engineering solutions, which must comply with the NZBC, and are based on:

- agreed upon fire safety goals, loss objectives, and design objectives
- deterministic and probabilistic evaluation of fire scenarios
- quantitative assessment of the effectiveness of design alternative against loss objectives and performance objectives.

The alternative design must meet the objectives, functional requirement and performance criteria as specified in the Building Regulations 1992. The Acceptable Solution can be used as a benchmark for the alternative solutions but not always as an equivalent (as most of the specific fire-engineering designers tend to do). In order to know which areas of the Acceptable Solution can be used a basis for the specific design equivalency, an understanding of the development and of the way the Acceptable Solution formulated is essential. However, the final assessment of safety is by opinion, fire engineering principle and some verification calculations. The performance based design requirements are not quantified in the codes. This results in a number of different possible design approaches and solutions, without a quantifiable level of safety.

As long as a designer can justify his or her design to meet the objective, the functional requirement and performance criteria of the Building Code, the design is deemed to be acceptable. In contrast to design in accordance with the Acceptable Solutions, the designers, reviewers and territorial authorities (TAs) can be held accountable in the future for loss of life in a fire. Unless they can clearly establish in the court of law that they have taken reasonable steps to ensure life safety in their design or review. Therefore, before embarking on an alternative design, the fire engineer must fully understand the design objective, the validity of the design assumption, the principle of

fire engineering and the requirements of the Building Act and the Building Code. ***They must go hand in hand, one without the other is in sufficient.***
One of the important reforms introduced by the Building Act was the opportunity for innovation created by the change to performance-based Building Code. That is to specify what a building is to achieve instead of the previous prescriptive regulations specifying detailed design and construction requirements.

However, many designers are quite reluctant to use specific fire engineering unless it is necessary, due to the following reasons:

- There is no verification method.
- The owner might not want to pay the extra cost for the design.
- It is difficult to demonstrate to what extent the design is safe because of lack of realistic fire curves.
- The designers and reviewers could face possible legal liability if things go wrong.
- It is hard to compete with the Acceptable Solution because it was established with a minimum safety requirement in mind.

1.4.3 Advantages of the 'Alternative Solutions'

As in other engineering disciplines, an alternative design may offer the designer and the client a number of advantages over the Acceptable Solution. The specific Fire Safety Design specifically addresses a building's unique aspects or uses, as well as client needs. It gives the clients an option to consider whether to follow the Acceptable Solution meeting their needs. For example, extra fire protection may be given to expensive machinery because the loss of production would have great repercussions to company's financial situation.

In performance-based codes, the code writers set the 'minimum' client loss and risk criteria by specifying objectives, functional requirement and performance which they perceived to be socially acceptable. It is difficult to evaluate what level of risk it might be, because it can not be quantified.

1.4.4 Disadvantages of 'Alternative Solutions'

There are, however, a number of perceived disadvantages to performance-based design. The 'Acceptable Solution' was established with due regard of national costs and benefits being taken into consideration. Consequently, it has some unfair advantage over the 'alternatives solutions'. As the 'alternative solution' is still very much at an early developing stage in this country, to judge the accuracy of the design performance of the building is not an easy task. The territorial authorities (TAs) may be reluctant to approve a design if they are unfamiliar with or do not agree with the approach taken, the objectives of the analysis or design, or the certainty or applicability of the tools used. However, the TAs may send the fire report, drawings and specification to be reviewed by an outside consultant. The peer reviewers could also have different opinions in each other fire engineering philosophy.

The Building Code does not require the property owner to address protection of his own property from fire. Therefore, most of the owners would not want to spend more money to protect their property from fire.

Also, a performance-based analysis and design process requires more engineering time for analysis, calculations, and design documentation than prescriptive design. Initially, this may appear to result in a high cost to the client because of additional design time. However, over the life of the project, potential construction or operational savings could be many times that of the engineering costs. There may also be concerns about the qualifications of the designer or the reviewer and with quality control measures used (or not used) to assure the adequacy of the design. As in prescriptive design, a change in occupancy or use may change fire protection needs. Therefore, it is essential to provide clear documentation of the performance-based design, which includes all design criteria and the goals and objectives of the client. It also points to the need for ongoing Fire Safety Management (i.e., inspections, testing and maintenance) to assure the Fire Safety Systems operate as intended and assure that the building use continues to be consistent with the stated goals and objectives. (Custer et al 1997).

1.5 Education

The new direction of fire engineering safety requirements has prompted many design professionals to seek education in fire engineering. Unfortunately, fire engineering, as a comprehensive subject is currently not being taught at an undergraduate level at tertiary institutions. The Timber Engineering course at the School of Engineering, University of Auckland, only contains aspects of fire engineering as it relates to the structural requirements of timber. The University of Canterbury has a small optional undergraduate course giving an introduction to fire engineering. In addition, a post-graduate engineering course leading to an ME was introduced in 1995 at the School of Engineering, University of Canterbury. The course emphasis is mainly on fire engineering principles leading to specific design to provide the 'alternative Solutions' approach. There are no courses offered in 'Acceptable Solution' anywhere else in New Zealand. However, there are the occasional short continuing education seminars offered. The BIA runs short seminars several times a year targeting education of TAs and the designers. The BIA also publishes a free monthly newsletter and offers free technical advice in relation to the Building Act and the Building Code. Even though these are very beneficial, the majority of designers are still self-taught and do not have an in-depth understanding of the Building Code's requirements.

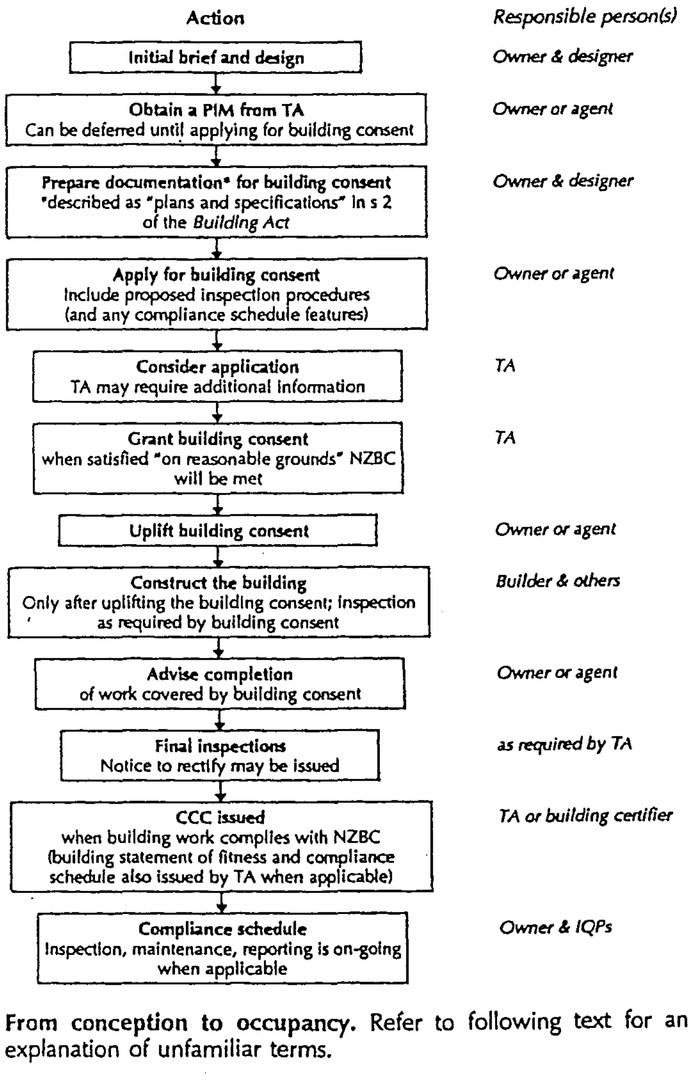
Four research students from Worcester Polytechnic Institute, Massachusetts, USA can substantiate this problem. In 1997 they came to New Zealand to study the social impact of the New Zealand Building Code 1993. What they discovered was that:

> 'The fire protection engineer has been greatly affected by the new Code. During design, many fire engineers are working beyond their qualifications. Fire protection engineering designers are currently practicing fire protection engineering with as little as a two hours seminar or a few correspondence courses which form the basis of the their fire safety engineering education. Presently, fire protection engineers and other members are taking on work, which they are not qualified to do' (Dennis B et al 1997).

CHAPTER 2 CURRENT PRACTICE

2.0 Building Requirements

Under Section 7 of the Building Act, all building work shall comply with the building code to the extent required by the Act, whether or not building consent is required in respect of that building work. However, Section 32 requires all building works to uplift a building consent from relevant TA before any construction work can be carried out. This procedure can be illustrated from the flowchart in "Guide to Building Act" (Warkworth 1999) as shown in figure 2.1



From conception to occupancy. Refer to following text for an explanation of unfamiliar terms.

Figure 2.1: Building Consent Application Flow Chart

2.1 Building Consent Review Process

Section 24 of the Building Act requires every TA to have the following functions under the Act in with its district:

- The administration of the Act and the regulations.
- To receive and consider applications for building consents.
- To approve or refuse any application for a building consent within the prescribed time limits.
- To determine whether an application for a waiver or modification of the Building Code, or any document for use in establishing compliance with the provisions of the Building Code, should be granted or refused.
- To enforce the provisions of the Building Code and Regulations.
- To issue project information memoranda, code compliance certificate and compliance schedules.
- Any other function specified in the Act.

Many of the review authorities do not have fire engineers on their staff, so they have problems in reviewing the alternative solutions presented in the reports. Outside consultants are often used to peer review the specific fire design documents.

2.2 Survey of approving Authorities

Buchanan (1999) conducted a survey for the nine largest city councils in New Zealand, to record their observations of changes over the past five years. The results of the survey are discussed in the following sections. The survey conducted was for commercial, industrial and public buildings, but not for domestic housing. The survey form and a summary of results are given in Appendix A.

2.3 Changes in Process

The new Building Code has resulted in many changes of process. The following is an extract from Buchanan (1999)

2.3.1 From Prescriptive Solution to designed solution

Before 1993, all designs were based on the prescriptive code (SANZ 1988). Since the adoption of the performance based code, the survey shows that about three quarter of the designs have used the new prescriptive Acceptable Solution, with 16% being minor changes form the Acceptable Solution and 9% using specific fire engineering design significantly changed from the prescriptive solution

The majority of the fire designs are still carried out by main designers of the building, the architect or structural engineer, and buildings requiring specific design are prepared by specialists. The numbers are different from city to city.

2.3.2. Who does the checking?

The survey shows that on average 80% of the submitted designs are checked in-house by TAs staff. Most of the in-house consents being checked are based on Acceptable Solution. Any specific fire engineering design applications are generally being sent out to the selected peer reviewers. Most of the TAs do not have a fire engineer on their staff. Therefore, the new direction has created a tremendous pressure on TAs staff, because they found themselves having to change their ways of thinking and approach after being used to the old system.

2.4 Changes in Results

New direction of building controls focus more on life safety whereas the old way on property protection. However, there is no sign of new buildings showing any signs of being unsafe. In fact, the additional benefits have been built into the new change because of periodic inspections of all buildings and the tougher regulations imposed on alterations or change of use.

2.4.1 From property protection to life safety

In the new legislation, there is a change in emphasis from property protection to life protection. According to the survey, the life safety for the building occupants has greatly improved while property protection for the building owner has reduced. Property protection for adjacent owners has remains very much unchanged.

The survey shows that there is a remarkable increase in active fire protection systems including sprinklers required by the code for life safety. The improvement may also result in lowering the property loss.

It is ironic that a code with the intention of reducing protection requirements in order to reduce costs for the building owner may have resulted in an increment in cost for many cases. Particularly for buildings built before 1991 and worst affected for those buildings built well before then. However, at least the fire engineering safety system of today is more realistic and practicable than ever.

2.4.2 From passive to active Protection

The new code has lowered the fire resistance ratings but increased the active systems including smoke and heat detectors and sprinklers. The new code requires the owner to ensure the safety of the building.

2.5 Change for major players

The survey reflects an ongoing problem with poorly educated engineers attempting to do fire engineering with up to 30% of all design being by them. From the author's own survey, the majority of the fire designers are not well familiar with the Building Act and NZBC.

Ever since the reform of the building controls, the Fire Service and Insurance Companies are losing ground in their role play of building safety design requirements. However, insurance companies are taking a passive role in fire safety and the Fire Service has gained increased responsibility for evacuation planning, building management and hazardous activities in buildings.

2.6 Changes in culture

Since the new legislation and new code, the fire designers are now discussing or disputing more about fire engineering design principles, fire safety and less about the old question of fire code. The survey shows a significant increase in knowledge about fire behaviour for both building officials and designers.

An important finding from the analysis of this survey is that one of the prime objectives of the change of direction was to reduce the building costs, however this has somewhat been defeated, especially for the upgrading of the old buildings. Although the passive safety system has been reduced because the property protection is now non-mandatory, the cost of active safety systems required for safeguard life has, in fact, overridden the benefit.

However, it is good now that we tend to talk more about fire engineering design principles than playing with words. With the skillful application of specific fire engineering principles and design, it is still possible to reduce overall design cost of the buildings.

CHAPTER 3 BUILDING ACT & BUILDING CODE

2.0 Introduction of Building Act

The Building Act 1991 is the end result of a series of reports, studies and research on building control reform, which started in 1979. One of the main reasons for the investigation was because there was no unification in building industries in New Zealand. Instead, there were a great variety of rules spread through a number of studies, regulations, bylaws and other controlled documents.

Prior to Building Act, building control in New Zealand operated through four distinct systems. There are Government departments, Local Authorities, Standards Association of New Zealand (SANZ) and other public and private agencies. Therefore, the development of a project can involve several bodies and sources having control over it.

The second major concern arising from the investigations was the ways by which controls were to be carried out. Prior to the Building Act 1991, the control documents governed how things should be implemented. Therefore, if a project did not follow the rules and attempt to use an alternative method it would not pass the controls. Instead, the studies preferred a performance – based code which would identify the desired ends to be achieved. This would result in increased flexibility in selecting the means to be used in achieving requirements of the Act (BIA 1997).

3.1 The Building Industry Commission - Objectives

In 1986 the Government set up the Building Industry Commission. The Commission's primary objectives were to:

- 'determine within a suitable economic framework the most suitable legal and regulatory provisions for the buildings and building construction and maintenance consistent with the public interest (including health, safety and amenity aspects); and
- in those areas where it is considered that such objectives are best achieved through minimum performance standards, prepare an appropriate, simplified, uniform

performance orientated national building code, which will bind the Crown'(BIC 1997).

3.2 The Commission's Report

The summarised Commission's Report by the Building Industry Commission (1990) maybe stated as follows:

- The New Zealand Building Code was introduced nationally and to be binding on the Crown. The code was to be performance based and confined to safeguard the occupants of the building and those directly affected by them. The provisions of the code would re-establish the social objectives which the building must satisfy, the functions required of the building to meet those objectives and the performance criteria for resulting behaviour in the use of the building and its component parts. The means by which the performance criteria could be met would not be prescribed and would be opened up to the innovation of new technology and practices.
- The proposed Building Act would provide for the code to be part of regulations until the Act. Thus, do away with the previous system which has controls spread through both the central and local government legislation. The Building Act and the code would become primarily the focus of the building control system.
- The establishing of a new body, the Building Industry Authority (BIA), which would be one source administer and review for the building control system. The Authority would be responsible for producing and updating the code and assess new techniques and solutions in the building industry. The Authority would be given the absolute power to interpret control documents and resolve differences between owner and territorial authorities in the application of the control provisions.
- Territorial authorities would be charged with the administration of the code. They would continue to be the office for building records and would issue consents for construction and occupancy, ensuring that the building owner had provided sufficient assurance of compliance with the codes provision.
- A greater emphasis would be placed on building owner and producers to ensure compliance with the code. The owner would be required to produce evidence of compliance so that the role of territorial authority would become a matter of

checking that appropriate measures and inspections had been undertaken rather than conducting those activities itself.

- The Act would allow for suitably qualified persons, approved by the Authority, to certify certain aspects of the building control processes as being in accordance with the codes provisions. These alternative procedures would give the opportunity for greater use of industry expertise to introduce an element of choice and competition in the building approval process. A similar process would be introduced for national accreditation of products and techniques. This would reduce industry concern over differing acceptance criteria set by territorial authorities.
- Consent for continued occupancy of a building in use would be based on the owner adequate maintenance of necessary function required of the building on which the users relied for their health and safety. Owners would need to show tha the code requirements had been met and that the building use had not been changed.

  The existing building would be intended to be included in the provisions, so that in time all buildings would be brought into current mandatory requirements.

With regard to fire and egress requirements, Section 6, of the Building Act emphasis the purposes of principles according to the following:

- Safe guarding people from injury or illness from a fire while escaping to a safe place.
- Safe guarding those conducting rescue operations and fire fighting.
- Preventing from spreading to neighboring properties.
- Protecting the environment from adverse effects of fire.

However, the Act does not address the prevention of fire damage to buildings and their content. This is considered to be the concern only of the building owner.

In determining the extent to which the matter concerning Section 6.1 of the Building Act:

(a) necessary controls relating to building work and the use of buildings, and for ensuring that buildings are safe and sanitary, and have means of escape from fire.

(b) the co-ordination of those controls with other control relating to the building use and the management of natural and physical resources.

'due regard shall be had to the national costs of benefits of any control, including (but not by way of limitation) safety, health, and environmental costs and benefits' in Section 6.3 can be applied to its benefit.

However, the 'particular regard' to the needs in Section 6.2 is meant to outweigh the 'due regard' to national costs and benefits under Section 6.3.

Section 6.2 requires:

- Safeguard people from injury, illness, or loss of amenity in the building during escape and rescue operation from fire.
- Protection of other property from fire
- Protection of the environment from hazardous substances.
- Provide access and facilities for the people with disabilities.
- Provide for the protection of other property from physical damage resulting from construction, use, and demolition of any buildings.
- Facilitate the efficient use of energy in a building.

(A number of experts quoted Section 6.3 without relating to the governing factors of Section 6.2. The author can not emphasize enough the important of knowing the Building Act and Building Code, which would be discussed in Chapter 4).

3.3 New Zealand Building Code

The Building Code is included in the Building Regulations 1992, issued in accordance with Part V1 of the Building Act.

Regarding fire safety requirements, the code consists of four categories.

C1 Outbreak of fire,

C2 Means of escape,

C3 Spread of fire,

C4 Structural stability during fire.

The main philosophy of the above criteria is based on:

1. Objective
2. Functional requirement
3. Performance

It sets minimum performance criteria in the public interest. Those criteria can be met in a variety of ways. Building owners may choose to meet more stringent standards. The performance requirement of the New Zealand Building Code is given in Appendix B. It is directly extracted from the Building Regulations, 1992.

3.4 The Approved Documents

The Approved Documents published by BIA are subordinate to both the Building Act and the Building Regulations. Approved documents must not be inconsistent with the Act or the Regulations and can not relate to contractual and commercial requirements.

The approved documents for fire and egress contain two distinct approaches:

- Acceptable Solutions
- Verification methods.

There is no Verification Method available in fire engineering design.

3.5 Acceptable Solution versus Alternative Solutions

The alternative solutions are not mentioned here in great detail because they will be discussed in the section of the Performance Based Design Philosophy in Chapter 5.

The 'Acceptable Solution' is a prescriptive document, which sets out what is to be done to achieve compliance with the NZBC. The practical application of the 'Acceptable Solution' is not as straightforward as the committees originally intended. It was planned to establish a simple solution which that the general designers, architects and engineers could follow with ease. Unfortunately, interrelation between clauses, different views of interpretation and the complexity of the contents have made it quite difficult for designers to follow. Under these circumstances the skill and art of the application of the 'Acceptable Solution' becomes very necessary. Without the knowledge and understanding of background of the 'Acceptable

Solution' and the practical aspects of the building works, the designers are not able to provide consistently accurate and good reports.

Nevertheless, the Acceptable Solution has significant advantages over NZS 1900: Chapter 5 because it includes comments explaining the intent of some clauses, good illustrations, and a fire engineering basis for some sections. The fire resistance ratings of walls and floors have been obtained using an equivalent for severity formula from the draft ISO Code (1993). The Acceptable Solution does not apply to buildings with a fire load higher than 1500 MJ/m^2 floor area. Therefore, specific fire engineering design is required for these buildings. Any buildings with insufficient ventilation such as dangerous goods stores and heavily fire rated buildings require a specific fire engineering design to calculate the 'S' rating. Any additional property protection provision must be based on specific engineering design because Acceptable Solution does not cover property protection in design. However, the majority of the fire reports do not cover property protection because it is not mandatory and the building owners, by and large, would not want to spend extra costs for fire safety systems above the minimum required by the Acceptable Solution.

The objectives and procedures for the specific fire engineering are not well established. The performance requirements do not quantify the level of safety of fire engineering experience, and judgement is necessary. Some designers for the alternative design seem to form their own theories and opinions without basic understanding of the Building Act and New Zealand Building Code.

EXAMPLE 3.1

Alarm to Firecell below Sleeping Purpose Group.

The applicant of this building consent proposed to add a sleeping accommodation above a small office in a storage warehouse. The approximate floor area of the sleeping accommodation added was $60m^2$ and the warehouse $1500m^2$. According to Acceptable Solution, this building was classified as SR/WM purpose group.

To achieve compliance with the Building Code, the following three conditions were required

- Appendix B: Fire Safety Precautions: Clause B2.4.2 of Acceptable Solution requires a heat or smoke detector type fire alarm to be installed below the sleeping floor and sounders extended to sleeping purpose group upper floor.
- The sleeping area also need to be a separate fire cell from the warehouse with a fire rating of FRR 30/30/30 according to C3/AS1 Clause 2.10.1.
- The means of escape for the sleeping purpose group need to be a safe path (unless the exits open directly to the outside of the building) in accordance with C2/AS1 Clause 4.2.1.
- The Approved Document Clause F7 requires that any fire alarm installed in a building should be deemed to comply with NZS 4561. NZS 4561 requires any alarm installed to be extended to the whole building.

The applicant only proposed to provide smoke alarms below the floor of the sleeping accommodation, sounders in the sleeping area with fire separation between the sleeping area and the warehouse. However, the designer failed to comply with the provision for the alarms to be installed throughout the whole building and providing safe path for means of escape.

Alternatively, the designer could suggest having the sleeping accommodation at the ground floor, thus doing away with the requirement of alarms to be installed in the building.

This simple example shows the interrelation and application of the clauses in the Acceptable Solution. It also illustrates the important of being well familiar with the Acceptable Solution and the other related codes so that the proper application of the Acceptable Solution can be achieved.

3.6 Peer Reviewers

Peer reviewers are used by some TAs as outside consultants, to review fire engineering design submitted for approval.

CHAPTER 4 CURRENT PROBLEMS

4.0 Introduction

This section is based on the observations at one Territorial Authority (TA) office in Auckland.

Currently, about 80% of residential situations fire designs and about 60% of commercial and Industrial fire designs do not comply with the requirements of the Building Act and Code. Subsequently, it takes excessive time and resources to correct the problems before building consents can be granted. Some of the changes required have created serious financial repercussion to the building owners.

A number of the designers rely on the TA or reviewers to rectify their problems. Together with substantial enquiries and disputes, the task of reviewer can be quite stressful and challenging at the same time.

4.1 Common Problems

The aim of this study is to reveal the types of problems facing the designers, TA and peer reviewers. It is intended to be constructive and not to discredit the designers of fire-engineering solutions.

The common problems found in fire and egress design are being listed under the following categories: -

- *Presentation and documentation.*
- *Attitudes toward fire safety requirements, the Building Act & the NZBC*
- *Integration between fire safety requirements & drawings*
- *Familiarity with and applications of the Approved Documents*
- *Fire rating at different boundary conditions.*
- *Residential community care accommodation.*
- *Performance based design philosophy (covered in Chapter 5).*

4.2 Presentation & Documentation

The fire reports from a few of the well-established fire consultants are generally well presented and documented. However, far too many reports from amateur fire designers are very poorly presented and documented. Fire documents are generally hard to find because they tend to be buried among the other submitted documents for building consent; this can be reversed with some education but still leads to frustration and time delays.

Frequently, the author of the fire report is unknown. As a result, it is hard to know who is actually responsible for the fire report being submitted. Is it from the engineer, architect, or owner?

The objectives of the reports are often not clearly defined. The writer frequently does not give a brief of the building type and its intended use. The report does not mention whether an acceptable solution or alternative solution is being used. All aspects of fire safety requirements are not always covered, such as the surface finishes are not always mentioned, or means of escape is not clearly defined. The methods and specifications for the proposed fire rating elements and requirements do not accompany the report. In general, the architect or engineer is not treating fire safety requirements as an integral part of the design. The finding is consistent the observation of with Caldwell (Caldwell et al 1999).

4.3 Attitudes toward Fire Safety Requirement, Building Act & NZBC

The attitudes toward fire and egress safety requirement can be categorised into six groups of people namely:

- The building owners
- The fire & egress designers
- The peer reviewers
- The territorial authorities
- The certifiers
- The builders

4.3.1 The Building Owners

Building owners are obviously in the industry to provide shelters and expect financial gains at the same times just like any other business organizations. Therefore, they would perceive any fire safety system to be an extra cost to them. Unless the consequence of a fire would cause extreme hardship and financial disaster, or the requirement from the insurance company, the owners are only prepared to provide the minimum fire safety system to the buildings as specified by the Acceptable Solution. Sometimes, a building owner may hire a well-qualified fire engineer in order to find a solution whereby the specified fire and safety requirement can be greatly reduced. However, for a building with a fire hazard category 4 (high fire load), a specific design is deemed to be automatically required, and the design cost is likely to be a lot more than usually expected for a building with lower fire load.

The BIA has outlined the responsibilities of the building owner as follows.

It is the owner's responsibility to:

- Notify the Council of any proposed building or alteration work
- Notify the Council of a change of use
- Apply for a building consent, and provide the necessary information to confirm compliance with the New Zealand Building Code
- Notify the Council on completion of building work
- Ensure that inspection, maintenance and reporting procedures are carried out where required by any compliance schedule
- Maintain the building at all times in a safe and sanitary condition

If these responsibilities are not fulfilled, the building owner may be liable for any accidents on his or her property. A majority of the building owners do not know as much as they may need to about the building code (Dennis et al 1997).

In practice, many building owners prefer to appoint other persons, such as designers, project managers, builders and subcontractors, to look after their interests and responsibilities. However, under the Building Act, the owner can be prosecuted if an offence is committed.

Fire & Safety Conflict

Building owners are more concerned with safeguarding their buildings from being burgled than from fire, because they perceive the probability of their buildings being broken into is far greater than from a fire occurrence. The Acceptable Solution C2/AS1 Clause 7.0 'Feature of Escape Routes' requires easily operated egress doors without using a key. This has created a tremendous conflict to different kinds of safety issues.

The latest 'draft' revision (BIA 1999) has identified the difficulty facing the owners, and this clause would be amended to allow the building owners to lock up their egress exits after business hours. This change will, no doubt, be welcomed by most building owners.

Some building owners would carry out building work without a building consent. Building works built without building consents would classified as 'unauthorized works'. No building consent can be issued once the works is done. However, the owner can apply to the TA for the works to be registered on the title if the works carried out was safe and to the requirement of the code.

EXAMPLE 4.1

Conflict between fire safety and security

Frequently, once the building consent has been approved, some of the building owners or tenants of the building padlock or block up the egress doors completely with all sorts of hazardous goods as indicated in the Photographs No.1 to No.10.

- Photographs No.1 & 2 show the exitways of a supermarket obstructed by shopping trundles and shelving.
- Photograph No.3 shows an egress exit door was blocked with trolleys.
- Photograph No.4 shows an exit way was blocked by pallets and plastic containers.
- Photograph No.5 show an egress exit was blocked by rubbish.
- Photographs No.6 to No.8 show egress stairs used to store all kind of materials.

- Photographs No.9 & 10 reveal after a fire the egress exit door had been padlocked which could well have cost the life of the occupants.

From the above examples, we can easily see the problems of how the means of escape are being abused by some of the building owners. This action has caused a tremendous problem and concern for the TA and the Fire Service. Basically, it is almost an impossible task to police because it requires so large resources. However, once it has been brought to light both the TA and the Fire Service would need to act accordingly. The owners could end up being prosecuted if they do not rectify the problem as instructed within a specified time.

The author could not stress more plainly the importance for the building owners to know the parts of the Building Act and Building Code relate to their responsibilities.

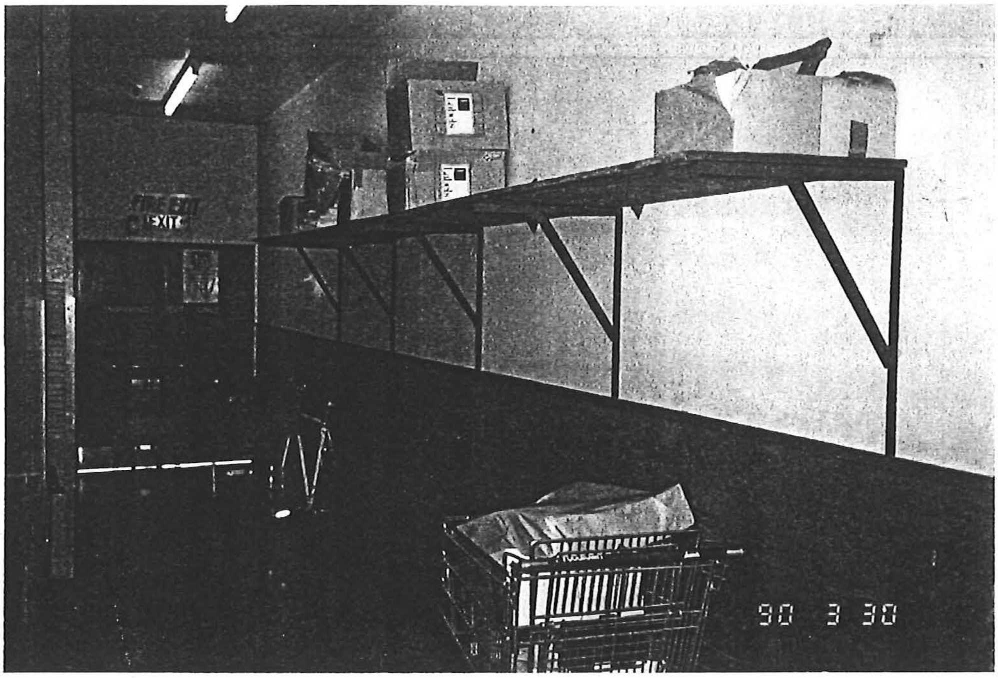
4.3.2 The Fire & Egress Designers

Unethical Approach

The attitude of the building owners can have a tremendous impact on the way designers think and design. After all, it is the building owners who foot the bill.

The designers are sometimes under pressure to come up with the owners' expectation – that is, to provide a minimal fire safety system or preferably none at all. This expectation could be awkward for the designers, particularly dealing with owners who have no understanding of the requirement of the Building Act and Code, their own responsibilities and liabilities. Some owners would make the statement '*We do not cook in here, why do we require a fire safety system? There is nothing here that can cause a fire? Why can't we use the balcony window as an escape exit? Why can't we build next to the boundary without having to provide a fire rated wall, the next door building is 15 metres away?' and so on.*

Photo 1



Exitways of a supermarket obstructed by shopping trundlers and shelving

Photo 2

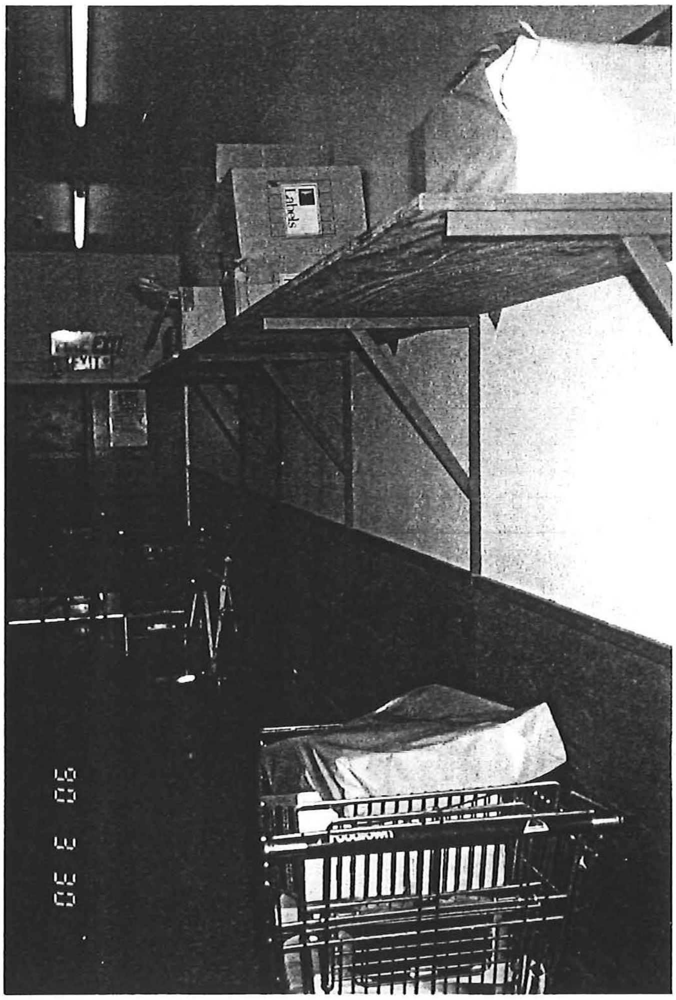
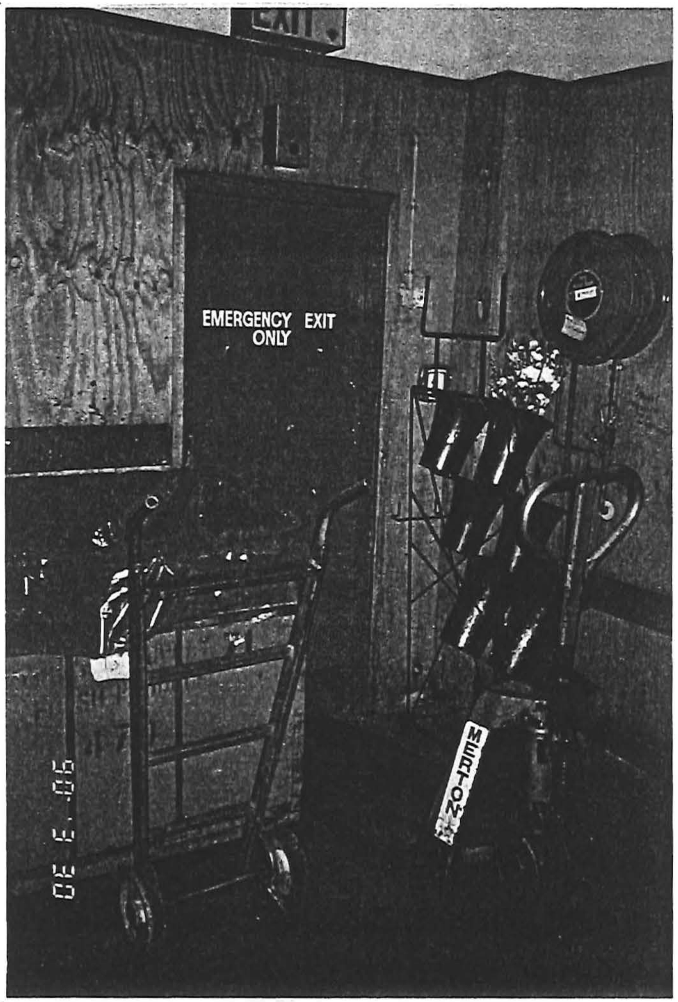
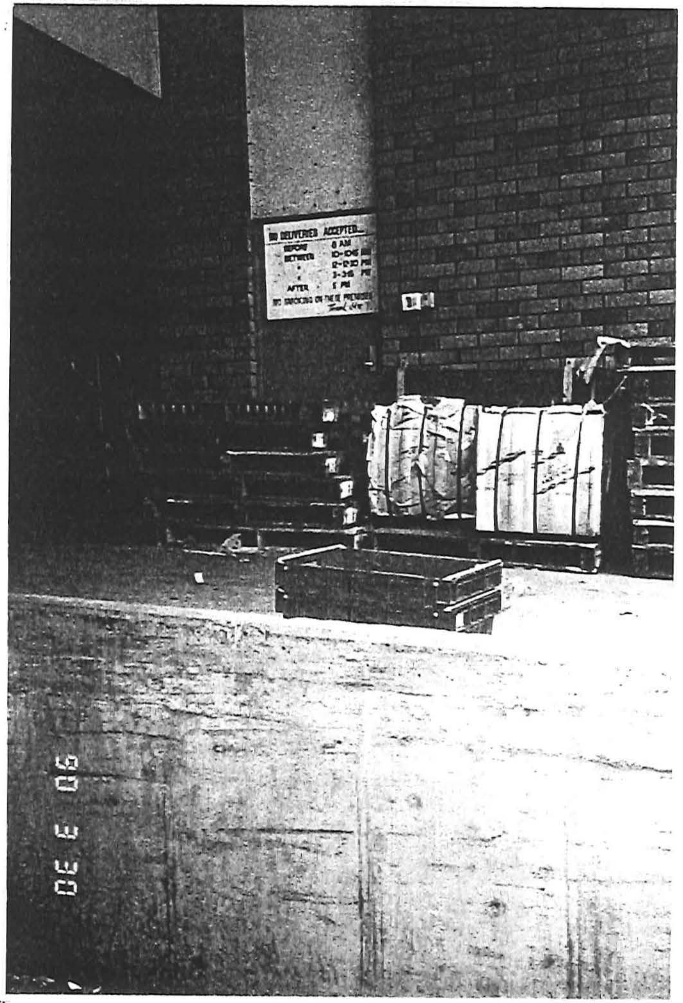


Photo 4



An egress exit door was blocked with trolleys

Photo 3



An exit way was blocked by pallets and plastic containers

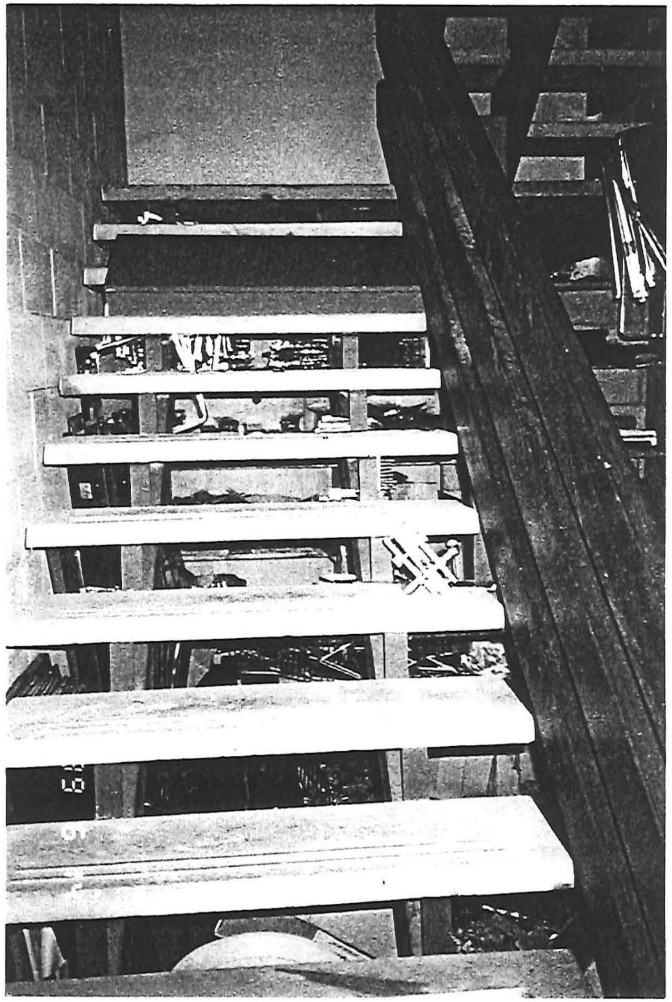
Photo 6

An egress exit was blocked by rubbish

Photo 5

Egress stairs used to store all kinds of materials

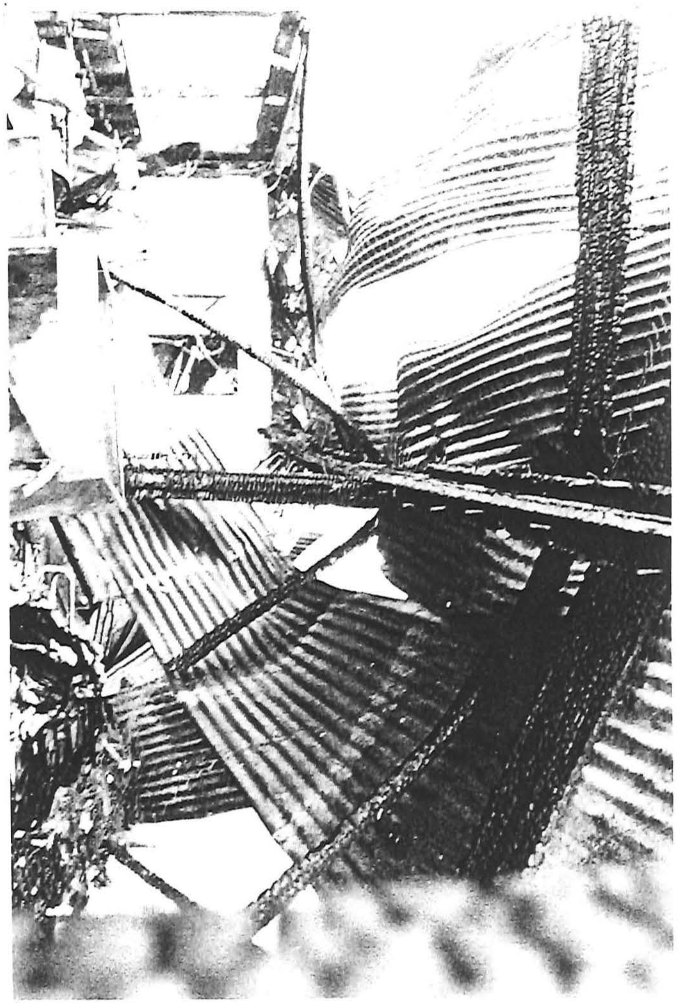
Photo 7



Egress stairs used to store all kinds of materials

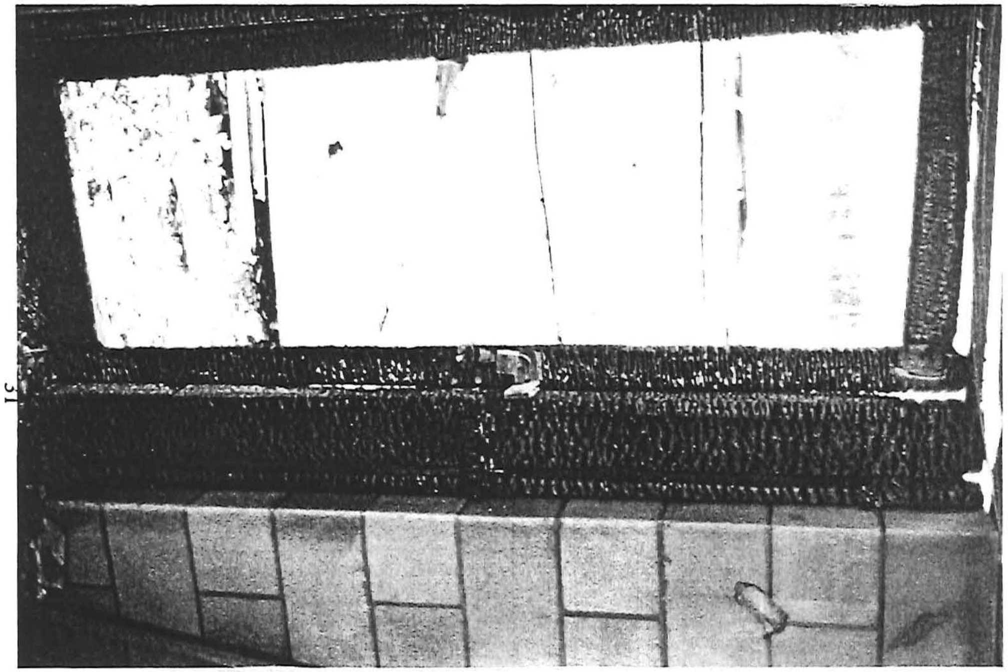
Photo 8

Photo 9



After a fire the egress exit door had been padlocked which could well have cost the life of the occupants

Photo 10



In order to please the owners or for fear of losing clients, a designer may be driven to adopt an unethical attitude, by not telling the whole truth in applying for a building consent. The designers may choose to be vague with the design objectives of the building or to provide incorrect information, which would otherwise lead to a more stringent fire safety requirement. It happens frequently with buildings under 'alterations' or 'change of use'

Loopholes & Unfair Advantage of the Acceptable Solution

Naturally the designers do their best to reduce cost for their clients. Designers may look for loopholes in interpretation of the Building Act and Building Code to avoid providing a necessary fire safety systems. In any ordinary design situation, there may be no benefit in using an alternative solution, because the Acceptable Solution was primarily established with the intention to provide minimum fire safety requirement. Some of the approved Acceptable Solutions may even be, to a certain degree **unacceptably accepted** because 'due regard' was given to national costs and benefits when deciding the extent to which controls are necessary to achieve the purpose of the Act (see Section 6.3) and refer Chapter 3.2 for commentary. Subsequently some unsafe design which satisfy the "Acceptable Solutions" are being approved compromising the principles of the Building Code to a certain degree.

It is in the author's firm belief that the BIA can be sued under Section 10 of the Building Act if the Approved Document does not measure up to objective, functional requirement and performance based design criteria of Building Code.

The following example illustrate some areas where the Building Code is being compromised and misinterpreted in the Approved Document. Examples will also be presented to show how designers are trying to assist owners to get away from fire safety requirements.

EXAMPLE 4.2

Building Separation Distance

- The 100% unprotected wall area being allowed for a residential dwelling with a one metre minimum distance from a relevant boundary, is extremely unsafe. Many residential dwellings have been damaged by an adjacent dwelling on fire, well in excess of the minimum separation distance.
- In the Fire Safety Annex Table C3, the calculations for the allowable unprotected area on an external wall is based on the principle of mirror image established by Margaret Law (1963). It has demonstrated clearly by Clarke (1999) and at the SFPE Radiation Workshop (Barnett 1999) that the Table C3 adopted from the Margaret Law's mirror image principle are unsafe.
- The 'draft' revision has adopted a more appropriate fire engineering principle and includes a series of much safer tables to replace the present Table C3. The development of the new tables was based on the allowable radiant flux of 30 KW/m^2 at the boundary line. The limiting radiant flux for low, medium and high fire hazard categories are than set one metre over the neighboring boundary as the design criteria. The new calculated distance to boundary will be increased for all purpose groups when the new draft is implemented. For some unknown reason, the draft code does not go far enough because the flame projection of the fire has not been taken into consideration.

Draft Revision Data for Distance to Boundary

Let us examine the design data for the draft revision:

- The NZ Building Code writers based the assumption that the fire fighting facilities in the urban areas will be available at short notice in the event of a fire emergency. The national average for arrival time of the fire service to a fire scene is 8 minutes. An estimate of exposure time for the neighbouring building before wetting down commences is approximately 15 minutes according to the code's writers. For radiation design criteria, three values of 30, 45, 90 minutes are selected for low, medium and high hazard categories before wetting commences. These times are then translated into safety factor of 2, 3 and 6 respectively.

Another assumption is the neighbouring dwellings are constructed of radiate pine with a 15% moisture content shows in Figure:4.1 below having the radiant flux limits of 19.4, 18.8 and 17.6 KW/m^2 respectively. These values have been rounded down roughly 10% to become 18, 17, 16 KW/m^2.

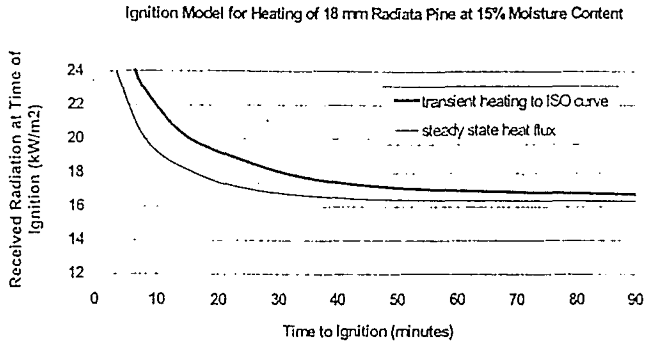


Table 4.1 extracted from Barnett (1999) shows a summary of the design data proposed to be used in conjunction with the limiting distance method to determine regulatory requirements in New Zealand.

Exposure Time before Wetting Down Commences Minutes	Maximum Temperature reached using Time-temperature Curve °C	Emitted Radiation I_E from the Firecell with Emmissivity of 0.95 kW/m²	Received Radiation I_{RC} at 1.0 m Beyond Boundary kW/m²	Received Radiation I_{RC} at Boundary kW/m²
30	842	83	18	30
45	902	102	17	30
90	1006	144	16	30

EXAMPLE 4.3

Wing or Return Wall

Same formulas are being applied to calculate for a wing wall or a return wall requirements at the boundary as shown at the following :

- C3/AS1 Clause: 4.5.1 Same building or on the same property, unprotected areas of external walls in different firecells are exposed to one another at an angle of 135° or less (see Figure 10). And either one or both firecells contain purpose groups SC, SD, SR or SH in the same or adjacent building, the unprotected areas shall be separated by a distance Do, where:

$Do = 2\,Dm - (\theta/90) \times Dm$, but in no case less than 1.0 m.

where

Dm = the mean of the minimum permitted distances (as determined from Appendix C for the given percentage of unprotected area) between the external wall and a relevant boundary for each of the two firecells being considered.

θ = The interior angle formed by the intersecting planes of the external walls.

- C3/AS1 Clause: 4.5.3 Unprotected areas in external walls facing a revelant boundary with other property at an angle of 135° or less (see Figure 10), shall be separated from that relevant boundary by a distance Db

  $Db = D - (\theta/ 90) \times 0.5\,D$, but in no case less than 0.5 m, where:

  D = the minimum acceptable distance between the external wall and the relevant boundary, as determined from Appendix C for the given percentage of unprotected area in that external wall.

  θ = The interior angle between a plane parallel to the external wall and the line of the relevant boundary between the two properties.

The adoption of either wing or return wall requirements in C3/AS1 Clause 4.5 (originated from the Canadian Code) is not strictly safe and correct, because the flame projection distance adopted in the Canadian Code has not been included in the New Zealand Code. However, even with the projected flame distance is allowed, the radiation over the neigbouring boundary may still not be acceptable for wingwall situation. However, it would have a conservative value if the return wall is being used. The inconsistency of the above cases has easily demonstrated in SFPE Radiation Workshop using Firesys (Barnett 1999).

Let us examine the cases being demonstrated at the SFPE Workshop. For a enclosing rectangle of 6×3 m light hazard fire category with a 100% opening:

- From the present Approved Document, the return or wing wall dimension can be calculated to be 1.5 m long.
- The wing and return wall based on the plot of Isorad Curves being adopted by the 'draft' revision in Figure 4.1 with an allowable radiant flux of 18KW/m^2 one metre across the boundary, can be calculated to be 2.25 m for wingwall and 0.5 m for the return wall.
- From the above figures, we can easily see that the value for the wing wall calculation is unsafe for the present Acceptable Solution in comparison to the 'draft' revision.

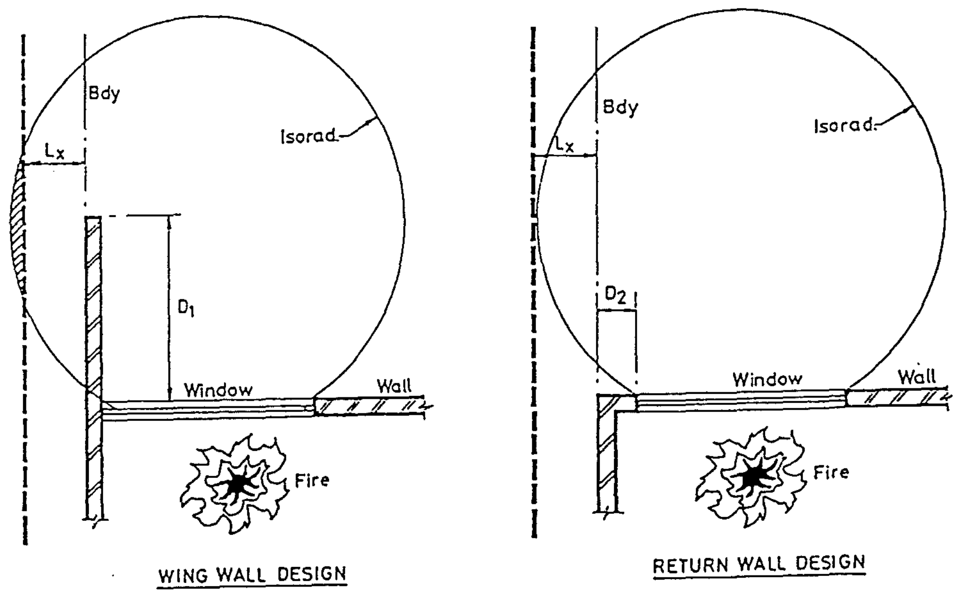


Figure 4.1: Wing Wall and Return Wall Design

(Barnett, C. R., 1999)

EXAMPLE 4.4

Vertical Flame Spread

C3/AS1 clause 4.4.5 for vertical flame spread (horizontal apron or vertical distance requirement) was demonstrated by experiments to be inadequate and unsafe (Langon Thomas 1972; Butcher 1983). Fire can spread to upper parts of the same building by the burning flame emerging from windows and igniting combustible materials which are adjacent to the windows. When a flame emerges from a window, it will tend to hug the face of the building and, in some circumstances, actually be sucked into open windows. The degree of flame geometry is largely dependent on the dimensions of the windows.

Figure 4.2 shows that without any wall above the burning window, the external flame tends to move upward at about the same distance from the front face of the building below as the window height. For this position of window, the flame trajectory is independent of the window width, i.e. it only depends on window height. The curves in Figure 4.3 show that the width of the window is as important in controlling the distance of the flames from the face of the building as is the window. Figure 4.4 shows the temperatures and the shape of the flame of the three different window sizes originated from an 1100°C temperature. From the studies, we can easily see that the vertical height of 2.5 m and horizontal apron of 600mm by Oleszkiewicz (1991) would reach an unsafe stage when the ratio of width / height is on the raise.

EXAMPLE 4.5

Loopholes

Sometimes a designer would exploit any loophole or not clearly defined clauses in the code to the advantage of his or her client. For instance, in subdivision development where a block of flats being built alongside one another, separated by an intertenancy firewall would be classified as an SR purpose group. In an SR purpose group, apart from the intertenancy fire wall between units, Acceptable Solutions C3/AS1 Clause 4.5.3 requires the designer to provide wing walls or return walls in accordance with Appendix C Fire Safety Annex, Depending on the width of each flat, the wing or return wall calculated could be significantly large. Thus the architectural and practical aspects of the building construction would be greatly affected. However, if the designer chooses to provide a separate firewall and footing and also provide a tiny gap of 10 mm or 25 mm between flats, the designer

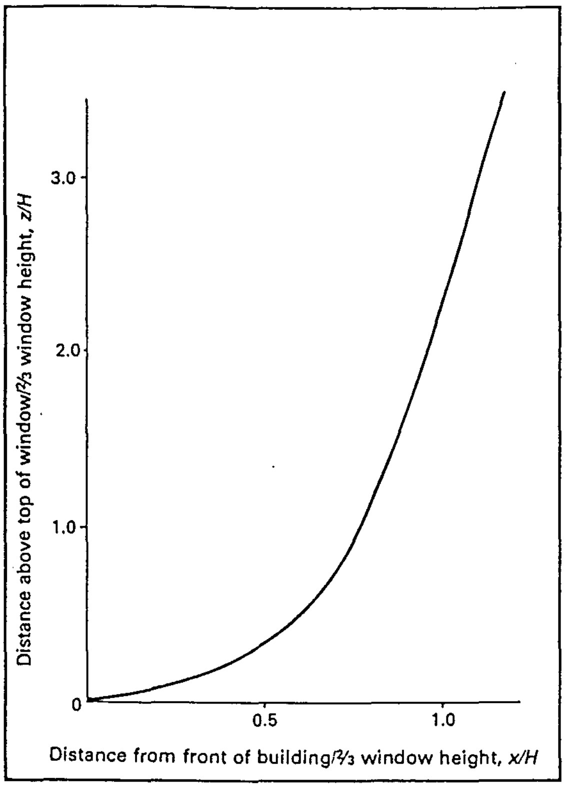


Figure 4.2: Shape of flame trajectory when there is no wall above the window (Ref Butcher et.al., 1983)

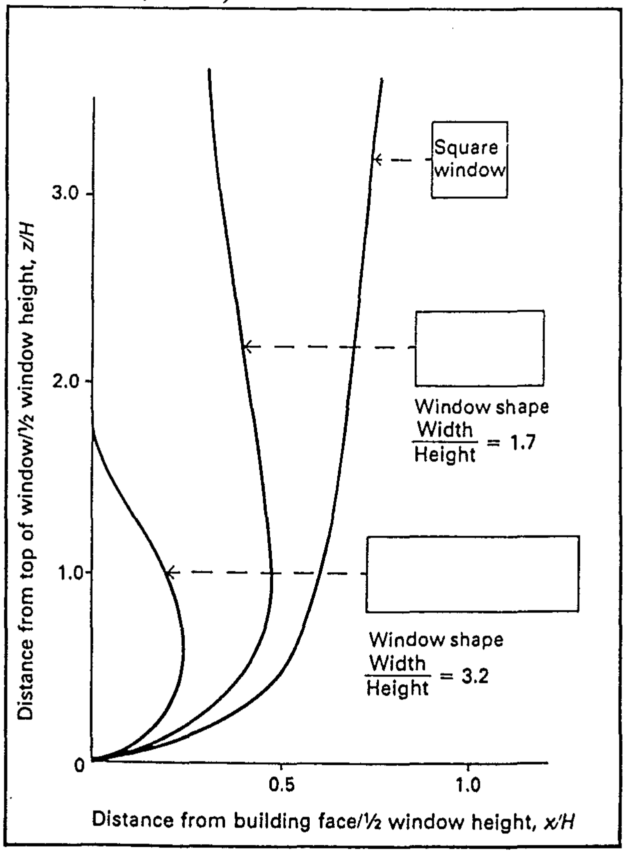


Figure 4.3: Shape of flame trajectory out of window when there is a wall or building above the window. (Ref Butcher et.al., 1983)

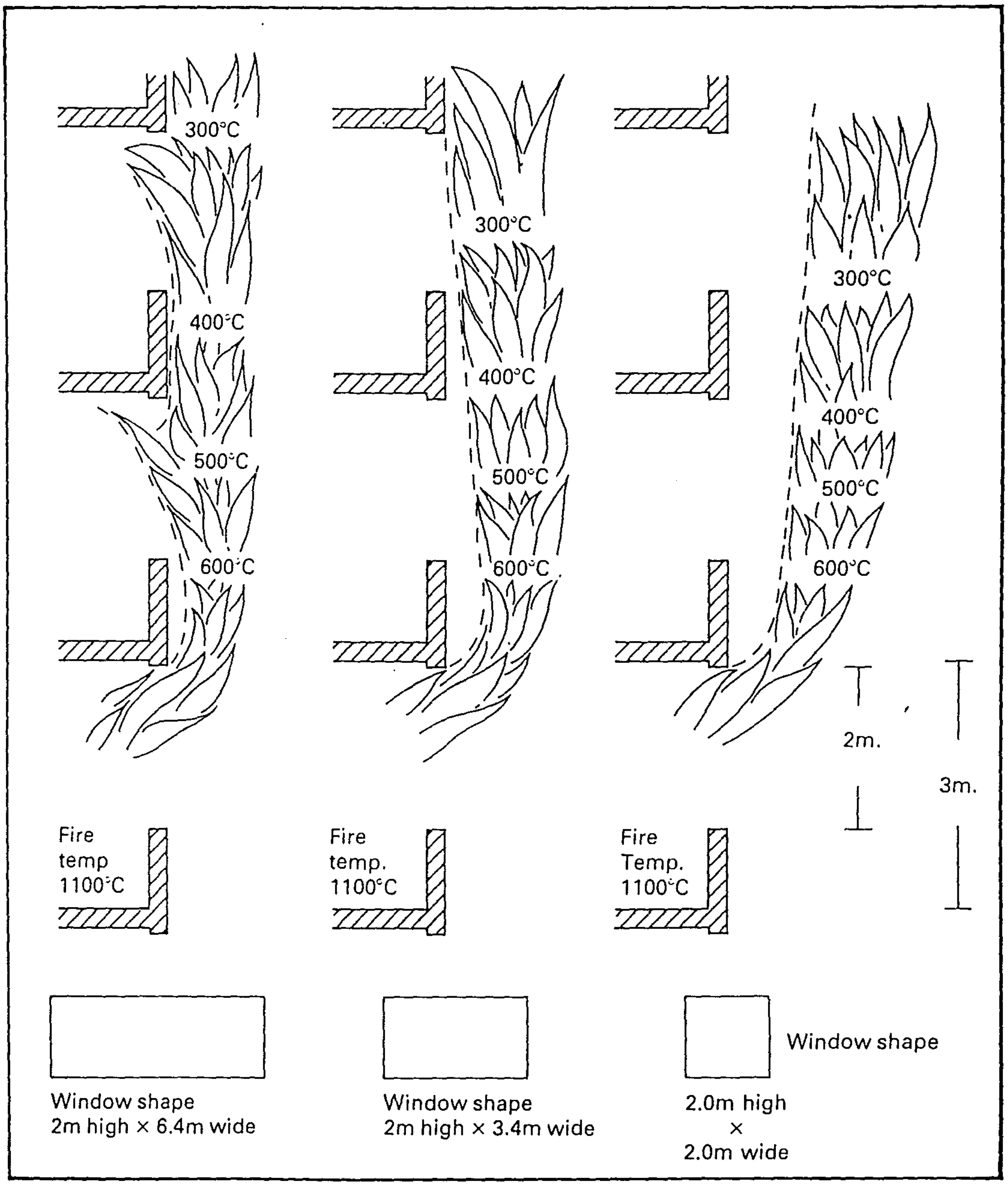


Figure 4.4: Flame profile and temperature for windows 2 m high and different widths. (Ref Butcher et.al., 1983)

can legitimately declare them to be in the category of SH purpose group. Under this purpose group, the owner only requires to provide a minimum of 500 mm fire rated wing or return wall at both ends of the intertenancy fire wall regardless of the dimensions of the individual flats. According to C3/AS1 Clause 4.3.6, for an SH purpose group, Appendix C for the calculation of distance to boundary can no longer applies. Therefore, this subdivision is deemed to comply, but the radiation across the boundary is excessive if wing wall is used.

Section 38 'Alteration' & Section 46 'Change of Use'

Section 8 of the Building Act states that existing buildings built before 1992 are not required to comply with NZBC. However, existing buildings require upgrading in two circumstances.

- When they are being altered (S38); or
- When there is a change in the use (S46) of the building. (including subdivision).

A building may already comply with the requirements of S38 and S46 before an alteration or change is made and, therefore, may not need further upgrading. That is less likely in the case of an older building, unless they have been recently upgraded. Each case must be looked at on its own merits.

The designers often do not state the objectives and nature of the buildings when applying for building consent. Therefore, it is not always easy for the TA to know exactly the fire hazard classifications for old buildings, unless a site visit is made, questions are asked.

However, for some circumstances, Section 34 .3 may be used by the TAs to grant a building consent if they can satisfied on reasonable grounds that the provisions of the building code would be melt if the building work was properly completed in accordance with the plans and specification submitted with the application.

Fire rating and safety system – Section 38

From Table 4.2, the 'alteration' of a building with a fire hazard of 1000 MJ/m^2 under the old regime would be equivalent to the new BIA 'Acceptable Solution' fire hazard, category 1, 2 and 3. In this case, any involvement in building alteration may not need to be upgraded substantially. However, the old building under the moderate fire risk classification 2000 MJ/m^2, would now be equivalent to the 'Acceptable Solution' fire hazard category of 4. Under this fire hazard category, a specific fire engineering design is required. Depending on the occupant loads and geometry of the building, the upgrading could be substantial.

The means of escape under the old Chapter 5 for the moderate fire risk classification would now face a more severe requirement. A building in the old regime with a fire classification of 2000MJ/m^2 would qualify for a allowable means of escape distance of 24 metres dead end open path under Chapter 5. However, if an 'alteration' is undertaking at the present time, the classification for this building would come under the WD purpose group with a Fire Hazard Category 4. The allowable total dead end open path would now only 8 metres. Therefore, this building would not comply with the 'Acceptable Solution' unless it is being upgraded.

However, if the designer or owner choose not to identify the true fire hazard classification of the building he/she might avoid to provide the necessary fire safety requirements.

The "draft" revision has relaxed these requirements by increasing both the allowable open and dead end path for all-purpose groups.

CHAPTER 5 FIRE CODE

Fire Risk Classification (FLED)	Life	Neighbours Property	Owners Property
Low (1000 MJ/m²)	Chapter 5 Code	Table 2	Tables 1 and 3
Moderate (2000 MJ/m²)	Chapter 5 Code	Table 2	Tables 1 and 3
High (4000 MJ/m²)	Chapter 5 Code	Table 2	Tables 1 and 3

FLED = Fire Load Energy Density

BIA FIRE CODE

Hazard Category (FLED)	Life	Neighbours Property	Owners Property
1 (< 500 MJ/m²)	BIA Code or SFE	BIA Code or SFE	SFE
2 (< 1000 MJ/m²)	BIA Code or SFE	BIA Code or SFE	SFE
3 (< 1500 MJ/m²)	BIA Code or SFE	BIA Code or SFE	SFE
4 (> 1500 MJ/m²)	BIA Code or SFE	SFE	SFE

SFE = Specific Fire Engineering

Table 4.2

'Change Of Use' – Section 46

Buildings under 'change of use' would require addressing Section 46 of the Building Act 1991.

Under Section 46 (2) a 'change of use' may require the upgrading of:

- the means of escape from fire; and
- access and facilities for people with disabilities.

Section 46 may also require the upgrading of:

- protection of other property (from fire and failure of building elements);
- sanitary facilities (see NZBC Clause G1);
- structural behavior (see NZBC Clause B1, B2) ; and
- fire rating behavior (see NZBC Clause C1 – C4).

The building must also continue to comply with the other provisions of the NZBC "at least the same extent as before the 'change of use'.

The meaning of the words 'change of use' are not defined. Without a definition or clear legal precedent to establish a particular meaning, the words 'change of use' should be given their 'ordinary and natural meaning', not necessarily the meaning that specialists such as architects or engineers may hold. The interpretation is that which an ordinarily informed person would apply to the words 'change of use' in the particular circumstances (BIA 1999). This interpretation penalises a lot of building owners because they might not only need to upgrade their fire safety system under the 'change of use' criteria, they also need to consider structure stability, their fire rating requirements and protection of other property; even though from a professional point of view, there is no change of fire hazard classification. In order to avoid this heavy penalty, the owners or designers might conceal or be vague with their information during their building consent applications. By doing so, they anticipate that their application may slip through under the classification of 'alterations' rather than 'change of use'.

Generally, provided there is no change in fire hazard categories, buildings built after 1991 would most likely achieve compliance. However, the older buildings built well before 1991, would move from a low fire hazard to a high fire hazard, when undertaking 'change of use' may require tremendous upgrading for the provisions for fire safety. In this case, the designer may only impress upon the TA that the building is only undergoing 'alteration' without mentioning that there is, in fact, a 'change of use'. This gets away without addressing protection of other property, and fire rating and structural stability.

4.3.3 Peer Reviewers

When TA's do not have the expertise to review the fire engineering design using "alternative solutions" or there a dispute has risen between TAs and the designers, especially selected outside consultants are often used to peer review the design.

This system usually works well. However, there are times where conflict could also arise between TAs and peer reviewers because of difference in opinions and reviewed philosophy being adopted by reviewers. The TAs are more legal and rules orientated and whereas the peer reviewers are more liberal and fire engineering principle orientated.

As the alternative design for fire engineering has only been established seven years ago in New Zealand, most of the peer reviewers are very likely to have absorbed their design philosophy and methods from similar sources. There is not yet an approved method for specific performance based design

Therefore, any unsound design philosophy or methods could possibly be filtered through the design acceptance without being properly challenged or tested. The reason could be simply because the concepts could well be initiated by a very senior or academic person in the field of fire engineering and there is no verification method for designers to follow. Another danger is that the peer reviewer might not be familiarised with the method or analysis adopted by the designer.

This will be discussed in more detail under the heading of "Performance based design philosophy" in Chapter 5. Any assumed philosophy adopted shall be required to stand the test in the Court of Law if a fire fatality occurs. To achieve the objective, functional requirement and performance criteria, the designers need to question themselves whether they have covered all the design aspects to the extent of it beingclassified complying the Building Code 'as near as is reasonably practicable' in the eyes of the expects.

EXAMPLE 4.7

Building under SR/CM Purpose Group

This is an example where there was a difference in opinion relating to a particular building consent application between the TA and the peer reviewer. It involved an existing two storey residential dwelling originally under the SH purpose group. The owner proposed to convert the ground floor into a retail outlet with a calculated occupant load of 80. It constituted a 'change of use'. Therefore, it was required to comply with Section 46 of the Building Act.

The purpose group was now under SR/CM classification. According to the Acceptable Solution, this building was required to comply with the following:

- **Radiation to Boundary**

(a) C3/AS1 Clause 4.2.1 Appendix C provides methods for determining the acceptable separation between a building and the relevant boundary. The distance is dependent upon the amount of unprotected area in the external wall, the size and purpose group applicable to the individual firecell, whether firecells are sprinkle fed, and on the purpose groups contained in adjacent buildings or clause 4.2.2. Alternatively when the distance to a relevant boundary is known, Appendix C provides methods to determine the acceptable unprotected area in an external wall, except when Paragraph 4.4.6 applies.

- **Fire Safety Precautions**

(b) C3/AS1 Clause B2.4.2. Should any upper floor contain a sleeping purpose group (SC, SD, SA or SR), all floors below regardless of purpose group contained, shall have heat or smoke detectors which activate alerting devices in all sleeping areas within the building.

(From Fire Safety Annex Table B1/2 , for CM purpose group of 80 occupants in a two floors building, the required fire safety system are **F30 3f or F15 4f**)

- **Vertical Flame Spread**

(c) C3/AS1 clause 4.4.5 and 4.4.6 are the requirement for vertical frame spread.

- **'S' Rating**

(d) C3/AS1 clause 3.2.4. Determining S ratings for fire hazard categories 1, 2 and 3.

For each firecell determine the ratios Av/Af and Ah/Af

Where Af	=	area of floor
Av	=	area of vertical openings in the walls
Ah	=	area of horizontal opening in the roof.

The S rating is calculated from the formula

$$S = Kte$$

Where

te (equivalent time of fire exposure in minutes) is determined from Table 1 and K is a variable having the following values.

K = 1.0 for unsprinklered firecells, or 0.5 for sprinklered firecell.

The 'S' rating was calculated to be FRR 30/30/30.

The designer chose to comply with item (a), (b) and (c), but not item (d). Under item (d), the designer would need to provide a minimum of FRR 30/30/30 for the ceiling of its supporting elements. However, the designer only proposed to upgrade the existing 9.5mm gib-ceiling by smoke sealed any gaps and replaced any defect ceiling boards. The 9.5mm gib-ceiling would only provide approximately 10 minutes fire resistance.

The designer justified his reason for not providing fire rating by stating that the heat detectors with the alarm connected to the top floor would have given early warning for the occupants. The peer reviewer agreed with the philosophy. However, the TA was concerned that human behaviour had not been taken into consideration because alternative solution was now being applied. The TA queried that what if the occupants above were to be elderly persons, intoxicated, on sleeping pills, or having hearing impairment.

According to research on human behavior, human responds to fire are unpredictable; some of the occupants may even sleep through an alarm. (Grace 1997; Duncan C 1999; Custer et al 1997; Bryan 1995). Would this design solution survive the definition of 'reasonably practicable ground' under Section 34 of the Building Act and NZBC in the Court of Law if a fire causing fatality?

The BIA 'draft' code has, in fact, tightened the fire safety requirement for all sleeping purpose group. According to Gerald (1999) residential fire claimed the most fatality in fire accidents.

EXAMPLE 4.8

Lift & Pool Incidents (None fire Engineering examples)

There are two recent incidents, which could serve as a constant reminder to all designers.

- An electrician crashed to death while maintaining the lift down below, and the lift designer was charged and sentenced.
- Another case was involving a swimming pool fencing inspector, who failed to gain access to the property to inspect the pool before a Code of Compliance was issued. Subsequently, a little child drowned in the pool because of inadequate fencing around the pool. The inspector suffered emotional and family relationship difficulty as a result.

4.3.4 Territorial Authorities

Prior to the enforcement of the Building Act 1991, the local authorities were the only entity processing and approving building consent applications. The attitude then of most of the Councils was regimental, the applicants were required to follow the codes procedure rigidly before a building consent could be issued. Since the establishment of new directions in the building controls, especially during the last couple of years, the TAs have taken a complete turn-around in their attitude. Customer focus has become the 'logo' of the Councils.

The TAs would do the best they can to assist the clients by providing guidance and advice when the clients made enquiries.

One of the most important objectives of the building code reform summarised by the Building Act was to introduce the private section competition for local authorities through the building approval process. Subsequently, there are new players entering the scene – the private certifiers who become the main competitors of the Territorial Authorities in the processing of building consents. Ironically, a majority of them were the ex-employees from TAs.

The author, on average receives between 15 to 20 phone calls from applicants per day. The calls would range from fire and egress enquiries to disputes in relating to the fire safety requirements the applicants were asked to provide in order to comply with the Building Act and NZBC. Therefore, it is essential that the TAs be well prepared and familiar with the Building Act and Building Code, so that they can function properly in their line of duty.

The TAs can use waivers and determinations to help them in reviewing building consent applications, as described below.

Waiver

Because fire engineering is a relatively new discipline and there are no set rules for performance based design criteria, TAs are often facing difficult tasks when confronted with tricky problems and situations. However, Section 34 of the Building Act allows a TA to grant a waiver to 'any document for use in establishing compliance' with the NZBC (see S34 (4) (a)) such as design calculations, design principles. Granting such a waiver is somewhat similar to accepting an alternative solution except in relation to matters concerning access and facilities for people with disabilities, swimming pool fencing and energy work. Before any waiver is allowed to take place, the applicant for a waiver needs to give the TA the supporting information that TA reasonably requires under Section 34 (2). Although waivers allow the "rules to be bent" (Acceptable Solution) a little from time to time, the objectives of the Act and NZBC cannot be ignored or modified. The TA must still ensure people's safety and health are safeguarded and, in all cases, the TA must act reasonably. This section enables TA to take a flexible approach and better attitude when dealing with applicants. Other than the TAs, nobody can give any waiver.

EXAMPLE 4.9

Boundary Wall

C3/AS1 Paragraph 3.6.6 forbids unprotected walls for a residential building within 1 metre of the boundary. If the building was to be constructed close to a boundary bordering a Council Reserve, or a right of way shared between two dwellings on the same property, that the TA accepted would not be occupied by a building or be built upon, then a waiver may be granted. In accordance with Section 50 and 89 of The Building Act, provided that a waiver is given in good faith, the TA cannot be sued for any unforeseen incident that might occur. Having given a waiver, the TA would need to advise the BIA. Information on waivers helps the BIA to monitor their frequency and subject matter, which can indicate a need for amendment to the NZBC. It is not necessary for TAs to advise the BIA before the waivers of approved documents are given.

Subjects where waivers have been issued

The BIA has records of 188 waivers being issued since 1993. These are summarized in their general categories below. As we can see from the result in Table 4.3 that 93 cases are fire related which represents a very high proportion.

Table 4.3: Waivers being recorded by the BIA.

C3	Fire Separation	77
B1	Snow loading horticultural use	44
C2	Means of escape	16
F4	Safety from falling	12
B2	Durability of roof cladding	5
E1	Protection from flooding	3
C4	Structural stability during fire	3
D1	Access	2
G6	Sound insulation	2
F7	Warning systems	2
G13	Composting toilet allowed	1
Others		21
Total		**188**

Determinations

Determinations (BIA 1999) can also be a channel of release for TAs. If TAs cannot decide whether waivers should be given or disputes between designers or peer reviews or TAs cannot be resolved, any of the parties can apply to BIA for a determination. The matters could be relating to the followings:

- Whether or not, or to what extent, particular building work or proposed building work complies with the New Zealand Building Code (the First Schedule to the Building Regulations 1992); or
- Whether or not the exercise by the Council of its powers under Sections 39 and 46 of the Building Act or the issuing of certificates under Section 224 (f) of the Resource Management Act 1991 in relation to the provisions of the New Zealand Building Code.

Under Section 19 (4), the applicant and any person who has made a written submission in respect of the application may speak at the meeting and call evidence in support. And under Section 2 the Authority will decide:

(a) To confirm, reverse or modify the disputed decision; or

(b) To determine the matter which is in doubt.

A determination can be challenged on a question of law by appealling to the High Court (see Section 86). Determination can be taken to the courts for judicial review-in order to decide whether or not the BIA is, in fact, acted correctly.

Determination is only a very small portion of the present building control system. By mid-1999 48 determinations had been issued, of the total determinations, only five fire related. However, the determination process is an important safeguard to ensure that any dispute or doubt in relating to New Zealand Building Code (NZBC) compliance, the technical issues can be examined by the BIA and a decision can be made reasonably quickly.

It is important for the TAs to be familiarised with the past-submitted determinations. Because they are good guidelines particularly in assessing a building consent which is similar to the one that already had a past determination.

EXAMPLE 4.10

Special Care Accommodation

A building consent application was lodged in relating to homes for the elderly under the classification of SC purpose group. The proposal involves a new 12-bedroom rest home. The designer had achieved other aspects of fire safety requirements in the Acceptable Solution except one inappropriate interpretation on C3/AS1 clause 2.8.5.

Clause 2.8.5 states "As an alternative to a non rated subdivision, a sleeping area may be divided to provide one or more suites. Each suite shall be a firecell with the fire separations having a FRR no less than 30/30/30. No suite shall contain more than 15 beds.

Comment:

A suite is a firecell, which may comprise one or more spaces (including bedrooms) and may include other facilities for the exclusive use of the occupants. Fire separations are not required with a suite. Examples may be found in hotels, motels, or residential facilities in a health care institution such as old people's homes, hospices etc.

Based on the above statements, the designer naturally interpreted that the whole building could be regarded as one suite and one firecell. Therefore, no-fire rating for the individual room was provided in this design. However, if the designer were to study clause 2.8.4 below closely and apply the fire engineering principle, he/she may realise that it was not the intention of the Approved Document to allow individual room specified by clause 2.8.5 to be non–fire rated unless they are only partially enclosed.

Clause 2.8.4 states "A sleeping area firecell may be subdivided with non-fire rated construction into smaller spaces each containing one or more beds provided that:

(a) Where full height walls are used, they enclose no more than 75% of the perimeter of the space, or

(b) Where more than 75% of the perimeter of the space is enclosed, a gap of no less than 400mm is provided between the top of the wall (or screen) and the underside of the roof or ceiling.

Comment:

It is important that firecell occupants are aware of a fire as early as possible. Fully enclosed subdivisions within a firecell can delay detection of a fire in other parts of that firecell.

Subsequently, the designer was asked to provide FRR 15/15/15 for each room for a sprinklered building. The bedroom doors were to be of an approved fire stop and smoke control doors fitted with self-closers to prevent fire and smoke to spread from the fire of the original. As a result, the owner was $40,000 over budget because of the fire safety requirements.

Admittedly, it was not easily understood in the first instance. However, the determination No.97/007: Fire safety alterations to a rest home – the meaning of "suite" is quite specifically being defined by the BIA as an individual room but can accommodate more than one person in each room. Had the TA not been familiar with the determination and approved this consent as it was submitted, the consequences could be devastating if fatality ever a fire occurred in this home for the elderly.

The 'draft' revision has changed the above two clauses to enable easier interpretation of the meaning of 'suite'. These changes are as following:

- C3/AS1 Clause 2.8.4. A group sleeping area firecell may be subdivided with non-fire rate partitions into cubicles, provided that each cubicle has no door, is open to a common space and the height of the opening is no less than 2100mm with a width of no less than 2100mm.

- C3/AS1 Clause 2.8.5 where sleeping areas in SC and SD purpose groups are subdivided to create suites, each suite shall be a separate firecell with fire separations having a FRR of 15/15/15. Suites may be subdivided with non-fire rated construction to provide separate spaces for sleeping, sanitary facilities and other activities. Where sanitary facilities are shared, those facilities may be contained within one of the suites, but entry from other suites must be through fire separations.

4.3.5 Certifiers

Certifiers are approved by BIA to certify fire safety and New Zealand Building Code (NZBC) compliance matters. At present, the majority of the building certifiers are approved as certifiers of residential buildings and only a few are authorised to certify compliance with all clauses of the NZBC. Therefore, it is essential for them to know the Building Act and Building Code.

A building certifier can issue:

- a 'building certificate'
- a 'code compliance certificate' (CCC)
- 'inspection reports' including monthly progress reports
- a 'building certifiers' notice of contravention of the building code

However, a building certifier cannot issue a building consent or grant a waiver – only the TA a can do that. A TA issues a building consent based on a building certificate being issued by a building certifier. The TAs are charged with the administration of the Building Code and an extended co-ordinating role between all regulatory bodies. TAs are also given the responsibility for keeping building records related to all building consents being issued.

Because of the competitiveness between the TAs and the certifiers, the certifiers are particularly vigilant and tend to monitor very closely how their building consents are being handled by the TAs. Depending on personality and the relationship between various TAs and certifiers, their attitudes toward one another can vary greatly. Disagreement could also happen from time to time.

EXAMPLE 4.11

Definition of 'Office' in residential building

Differences in opinion can also arise between TAs and certifiers. This is a case where a residential certifier submitted a building consent for pim application with the word 'office' written on one of the rooms on the drawing. The TA questioned the certifier whether it was an office for business use; and if it was, the consent would be classified as a 'commercial' consent which would be outside of the scope of the certifier. Because there is no definition of 'office' in the Building Act, the word must be treated as a layman would normally interpret. Therefore, this dwelling should be under the commercial classification. The TA insisted that the owner should produce a written statement stating that the office was for personal use only.

The certifier argued that they did not have to change the word or produce a statement from the owner because the house was clearly a residential dwelling. Finally the opinion of BIA was sought. The BIA gave the opinion that if the dwelling was clearly a "household unit" you could call the room whatever you like. The TA interpreted that unless a written statement was produced to TA, there was no certainty that the room was for personal use or commercial use. There were numerous unauthorised cases where offices in residential dwellings were being used for commercial purposes, even with employees from outside working in the dwellings.

Especially in the year of the millenium, more and more buildings are built to cater for dual purposes.

4.3.6 Builders

Not all builders know the Building Act and NZBC, and not all builders are familiar with fire rating requirements. From the builders point of view, their job is to build the buildings according to the plans and specifications supplied to them. The priority of the builder is to make money. Therefore, they are always anxious to get on with the job and finish it and move onto the next one.

Some builders offer wrong advice to owners without realising that it could create problems for the owners in the future.

EXAMPLE 4.12

Fire rating between sleeping/other purpose groups

One builder built a garage adjoining the existing dwelling without a firewall for a building owner. The builder was informed by the owner that he would like to use that garage for a sweet manufacturer in the near future.

When a building consent was lodged at a later date for the application of 'change of use' for this dwelling, the purpose group of this building had now changed from a SH to a SR/WL purpose group. The owner suddenly learned from the TA that he was required to provide a fire rated wall, wing walls between the garage and the dwelling to achieve compliance with the Building Act and Building Code. He was also required to address radiation to the boundary and the fire rating to the soffit of the roof eave as required by the following clauses.

According to Acceptable Solution C3/AS1 Clause 4.1.1 external walls and roofs shall be constructed to avoid:

(a) Vertical fire spread up the outer face of the external wall of any building containing purpose groups SC, SD, SA or SR.

(b) Horizontal fire spread by thermal radiation or structural collapse, which could endanger

 (i) other property, or

 (ii) adjacent building containing purpose groups SC, SD, SA, SR or SH, or

(iii) external safe paths.

Comment:
C4/AS1 identifies which primary elements providing structural stability during fire are required to be fire rated.

There is no change in the 'draft' code for this clause.

4.4 Integration of Fire Safety requirements with drawings

The problem of integration between fire safety requirements and drawings has created one of the worst nightmares and frustration for the TAs officers. Almost all the fire designers, to a certain degree, neglect this requirement. The majority of the problems, in particular, are the transferring of fire rating details such as fire rating wall, ceiling, penetration of fire wall and their supporting elements onto the drawings.

The designers take the attitude that the moment they complete the fire reports and specification, their jobs are finished. This is far from truth. In the Building Act:

Section 33 (2) requires every application for a building consent to be accompanied by the plans and specifications

Section 2 defines 'plans and specifications" as the documents "according to which a building is proposed to be constructed......'

Section 34 (2) in effect requires a TA to be satisfied on reasonable grounds that the proposed building work would comply with the building code if 'properly completed in accordance with the plans and specifications'.

A TA is not permitted to issue a building consent unless the plans and specifications are sufficient to define the completed building work in its entirety. It is common practice in building contracts to provide that the plans prevail over the specifications. If so, then the specifications cannot correct errors in the plans but can specify details not shown in the plans.

Therefore the designers can not assume that the builders would automatically know what to do. In fact the buildings generally build according to drawings supplied to them. Even when the fire rating details are being integrated with the drawings, they are often either incorrect or incomplete, especially the household unit / granny flat details.

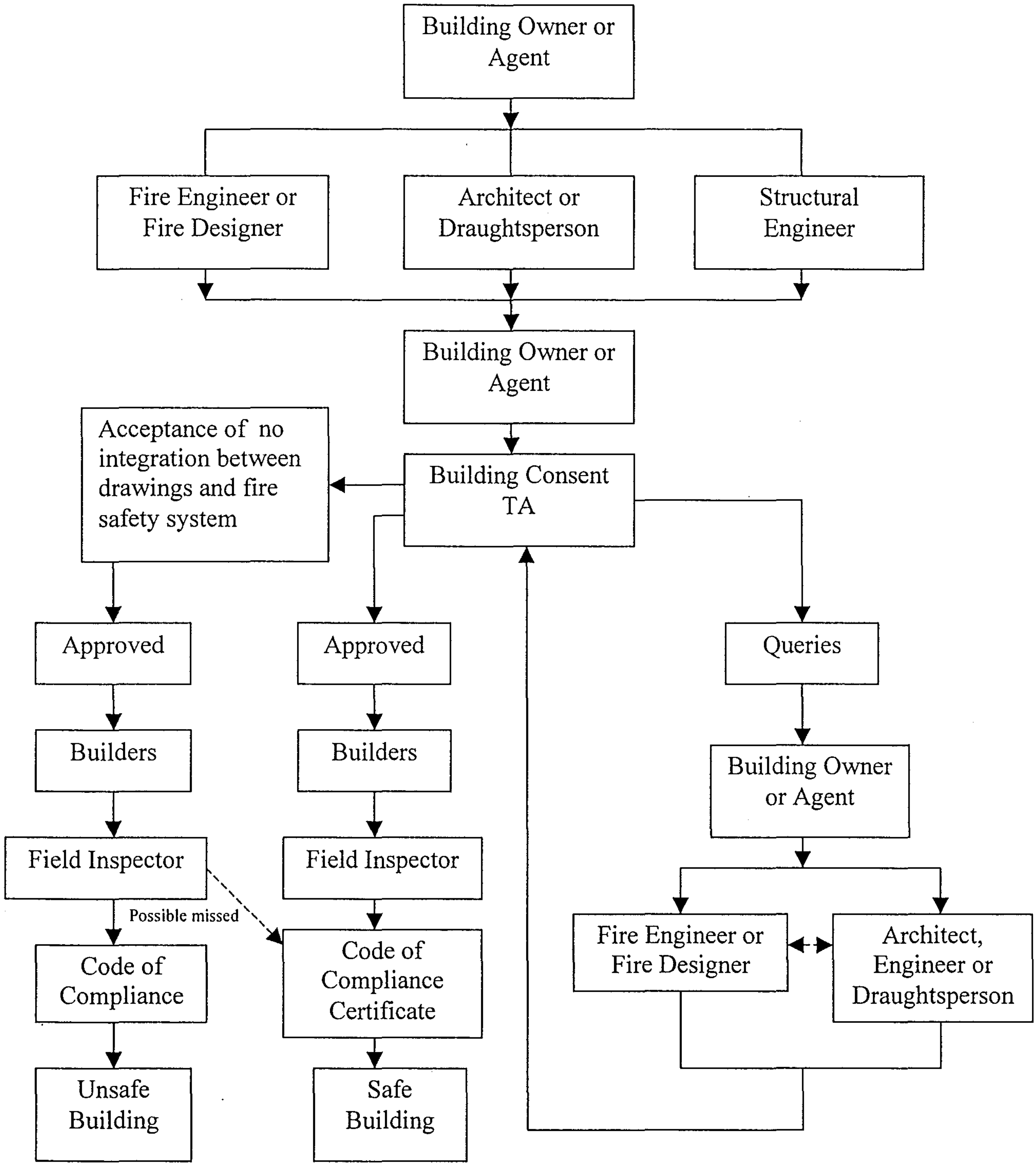
Frequently the building owner or agent may independently hire a fire engineer to prepare a fire report, an architect or draughtsperson to provide drawings, and a structural engineer to provide engineering calculation. Sometimes, either the architect/ draughtsperson or engineer may also write the fire report. Once each individual has completed their tasks, they would hand over their document to the owner or agent for a building consent application.

Unless the TA queries the fire design, there could be little communication between the parties involved in the project. The procedure during the building consent stage the author's vision is being illustrated in Figure 4.5: Flow Chart during Building Consent stage.

The majority of the fire designers are not professionally trained to prepare fire reports and most of them do not fully know the fine-art-of-detailing. Some details could be tricky, because the designers might require an understanding of the fire engineering principles before he can produce one correctly. Therefore, they are inclined only to prepare the fire reports and leave the details to the architect/draughtsperson to complete. There is a great possibility that the architect/draughtsperson also do not know how to provide fire rating details correctly. This could become a case of the '*blind leading the blind*' syndrome.

The above situation can subsequently make the TAs officials task extremely stressful. It can also be dangerous if the TAs officers do not have the sound knowledge and understanding of the fine-art-of-detailing and the ability to identify the mistakes. The TA officials are only human, therefore, mistakes can occur in consent checking. When that happened, every effort would normally be made to rectify the mistakes.

Figure 4.5: Flow Chart at Building Consent Stage.



4.5 Familiarity with Approved Documents

In the author's experience as a reviewer, many fire engineers are not very well familiar with the Building Act and Building Code. Some TA and reviewers are also not familiar with the Acceptable Solution. Under these circumstances some of the building consents being approved may be unsafe. Designers are depending on the TA or reviewers to rectify their mistakes.

The fire reports from the general designers are often poor and not thorough. The problems could vary from further information required, to major changes or additions to the fire safety requirements. Hence, it could create a huge impact on the owner's budget of the owner if wrong advice is given at the earlier stage.

EXAMPLE 4.13

Boundary Wall Requirement

A design-and-build developer submitted his proposal for building consent on behalf of an owner. His proposed 80 metres long warehouse was located next to the boundary line without any fire rating. His reason for doing so was simply because the proposed warehouse was separated from the neighbouring warehouse by the neighbour's right-of-way adjacent to the boundary.

Acceptable solution C3/AS1 Clause 4.2.1 under the heading of Building Separation requires building owner to address the distance between the building and the relevant boundary. Subsequently, not only a fully fire rated wall was required for the boundary, but a major re-design works was also carried out to provide firewall stability problem of the boundary wall.

EXAMPLE 4.14

Granny Flats SR purpose group

A building consent was lodged by a couple for the fire rating of the existing walls between three granny flats in a dwelling. They purchased the building from a real estate agent one and the half years ago. At the time of the purchase, the real estate agent had it in writing that the building would need to be upgraded to comply with the Building Code, because there were no fire rated wall and sound insulation between the three granny flats.

With no knowledge of its implication, they bought the dwelling and rented them out to generate an income. One year later, one of the tenants moved out and sued the owners for letting him a dangerous and stressful unit. The tenant was awarded a half year rent reimbursement by the Court because of lack of fire safety and excessive noise, which caused stress.

EXAMPLE 4.15

Sports Center CL purpose group

A fire designer prepared a fire report for a sports centre. The centre consisted of a 100m^2 mezzanine floor and 400m^2 ground floor in area. The occupant density was 0.5 person/m^2 with the calculated top floor having an occupant load of 50 and the calculated bottom floor with occupant load of 200. According to Fire Safety Annex Table A1: Purpose Groups, it was classified as CL purpose group with a Fire Hazard category of 2.

As for the fire safety system, the designer used Table B1/1 Fire Safety Annex, under a two floor building as indicated in the enclosed box below.

For a CL purpose group with a total occupant of 250, the fire safety requirements can be either of the followings indicated in the table.

Full Floor	Intermediate Floor
F30 4, 9, 14, 16 ad	F30 5, 10, 14, 16 ad

(The "draft" revision has been simplified Table B1/1 to B1/7 in order to make them more user friendly.)

Either of the above systems being adopted would cost the owner $30,000 more than what he wished to spend.

However, the designer overlooked Clause B2.8.3 in Fire Safety Annex. Clause B2.8.3 states that where one or more intermediate floors occur at approximately the same level, (not one above the other) in a firecell, entry to Table B1 shall be for a single floor building using the total occupant load in the firecell, and the safety precautions adopted shall be those taken from column 2, 3 and 4 provided all the following conditions are satisfied.

(1) The firecell is under one management.

(2) *The total area of all intermediate floors is no more than one-third the area of the lower floor.*

(3) The F rating is selected from column 5 of the Table B1 for a two floor building using the total occupant load on those immediate floors, and the FRR's of the intermediate floors are based on the F rating, but in no case shall be less that required by *C3/AS1 Paragraph 2.2.4.*

C3/AS1 Clause 2.2.4. Intermediate floors

Intermediate floors and their supporting primary elements within the firecell shall have FRR's of no less than:

(a) The F rating determined from Table B1, when the spaces above and below are open, or

(b) The greater of the F rating or 30/30/30, where space above or below are enclosed by building element which are not fire rated.

(The 'Draft' has changed the 30/30/30 fire rating to 15/15/15. It is the author own opinion that NZ Fire Service may not agree to this change.)

The mezzanine floor of this building is less than one third of the building floor area. Therefore, the building can be classified as a single floor building.

From B1/1, for a single floor occupant load of 250, the fire safety precautions would now only require a **FO 2* & 16 ad***

(* Only applied to cinemas and theatres)

FO is overridden by C3/AS1 Clause 2.2.4 (b) as indicated in clause B 2.8.3(c). Subsequently, an amended fire report was submitted with no fire safety system required, except a FRR30/30/30 for the mezzanine floor. The owner was pleased with the outcome.

The Table from the "draft" revision has simplified the system considerably. The above examples have clearly demonstrated the importance of knowing and understanding the NZBC and its application.

4.6 Fire Rating at Different Boundary Conditions

The Acceptable Solution has not clearly defined types of boundary which required different degrees of fire rating. Subsequently, there are far too many fire safety designers not familiar with the exact application of the fire rating required for various types of boundary conditions. The consequence could be devastating for the owners and the designers, especially for the development of sub-divisions.

Frequently, the architect and fire designer would carry out with the planning and developing of a sub-division according to what they perceived to be acceptable and correct. They might pre-sell the building of a sub-division with the drawings they have presented to the client at preliminary planning stage, only to discover at the building consent application stage that the boundary conditions they designed does not, in fact, complied with the Building Act and NZBC. The developers would end up having to go back to their clients advising them of the required modification in order to achieve compliance. Some clients might even withdraw agreement to their purchase as a result of the modification.

Therefore, before the architect and fire safety designer undertake a complex sub-divisional development, it is wise for them to meet with the territorial authority for a preliminary discussion to establish the correct design criteria at boundary condition.

To avoid confusion the author would like to run through the definitions for different types of land tenure and their fire rating requirements in relation to their boundaries.

There are three commonly used types of land tenure most encountered in fire safety design:

- Cross Lease or Company Lease Tenure
- Free Simple Tenure
- Unit Title Tenure

4.6.1 Cross Lease or Company Lease Tenure

The building, flats or units held under company lease or cross tenure are held in one ownership but are technically leased from the other occupants or owners. If a lease is for more than 20 years then it's considered to be a subdivision and individual Certificates of Title are issued for each flat or unit and the boundary becomes the outline of the flat or unit, including the floor and ceiling for multi-story buildings. In this case, fire rating issue needs to addressed between units.

The buildings or flats can be leased for a term of 19.99 years without being considered separate legal allotments and the legal boundary will be the primeter of the land on which all the flats or units are situated.

It is important to note that as far as fire rating for cross lease or company lease tenure is concerned, it is very much depend on the ownership of the units. If everything is owned by one owner, there can be no fire rating between units provided that the lease for each unit is limited to19.99 years. Because according the Building Code, the owner does not have to protect his own property. However, If the units are to be owned by different owners, but still under one lease title, a compulsory intertanancy firewall between units would be required because of the protection to other property is now applied.

EXAMPLE 4.17

Building under One Fire Cell

A building consent was lodged for an educational centre in one of the unit under a company lease tenure. *One owner owned all units.* The centre had less than 100 people. Therefore, it was classified as a CS purpose group with a fire hazard category of 1. However, when the building inspector made a site visit, he discovered that there was a clothing manufacturer adjacent to the unit with bulk storage well over 3.0m. The factory was classified as a WD purpose group with a fire hazard category of 4. There was no firewall between the two units. Therefore, the two units were under one firecell. Subsequently, the educational centre was also classified as a WD purpose group unless a total fire load calculation to prove otherwise. A much stringent fire and safety requirements was required as a result.

EXAMPLE 4.18

Type of Building – SH purpose group.

A cross lease owner proposed to build his building at the notional boundary between his neighbor without any fire rating. There was adequate separation distance between his house and his neighbour.

Matter of dispute – whether a fire-rating wall was required at the boundary.

The TA requested that the wall of the building adjacent to the boundary be fire rated because the Acceptable Solution Clause 3.6.6 requires walls that are within 1.0m of the relevant boundary to be fire rated at both sides.

The applicant disputed that for SH purpose group, his dwelling only needed to be 1.0m away from the relevant boundary. Therefore, all he had to do was to shift the notional boundary 1.0m toward the neighboring property. After shifting, there was still more than 2 metres distance from his dwelling to that of the neighbor's. He also reminded the TA that the whole property was registered under a single title.

The TA argued that the allocated use of land to the neighbouring owner would automatically give the neighbour the exclusive right to use that portion of the property. Therefore, the shifting of the original allotted notional boundary toward the neighbor would not be achieving the safeguarding of the other property from the effects of fire. It is one of the objectives, functional requirements and performance criteria in the NZBC, 1992.

The author wishes to remind the designer that a house owner was successfully sued the Council for the damage to his tree caused by the radiation emitted from the fire in the adjacent dwelling.

4.6.2 Simple Fee Tenure

The land under the simple fee tenure is registered under one owner and does not identify any building on the land. The boundary is the perimeter of the property. Therefore, if an owner wishes to sub-divide the land into separate simple fee titles either with the boundary being in the close proximity to the building or adjacent to it, he/she is quite entitled to do so without considering any fire rating requirement at the new boundary.

However, TAs may serve the owner a dangerous building notice immediately after the sub-division title is released. Therefore, it is wise to consider the fire rating requirement during the sub-division stage to avoid any future legal complication.

4.6.3 Unit Title

The land unit under title is corporately registered under a group of owners. Each owner has their own individual Certificate of Title and has complete control over their respective unit and accessory units. Permission must be sought and granted by all owners prior to any works being done within the common area, and for legal purpose the addition of any building on the Unit Title plan will require the TA's approval.

The boundary of the allocated land would thus become the relevant boundary of each owner. The distance to the boundary from each building and accessory units must be measured according to the revelant boundary. Any deviation from the limitation would require legal agreement between owners.
The Unit Titles act 1972 was created primarily for strata units, which are units, stacked on top of each other. The boundaries then become 3-dimensonal as they follow the outline of each individual unit.

Both horizontal and vertical flame spreads are required to be addressed. Each unit also needs to be separated from the other with a fire rated floor. Realistically it is very difficult to practically prevent vertical flame spread without fire rating the whole vertical wall.

These kinds of situations are common in city high rise apartments. Most of them will not be safe if exposed to a full developed fire.

EAXMPLE 4.19

Spandrel / Apron

Type of building – 18 attached multi-unit residential and commercial building. Each unit consists of ground floor garage Intermittent Activities IA, first floor office WL and second floor sleeping SR purpose group. Building designed to comply with the Acceptable Solution except radiation to boundary was calculated using Firecalc.

Areas of dispute

The designer provided all the requirements except addressing the prevention of vertical fire spread from WL lower floor office to SR upper floor sleeping purpose group.

However, the following conditions from the Acceptable Solution needed to be fulfilled before the building could comply with the Building Code:

- C3/ASI Paragraph 4.4.6 where firecells containing SC, SD, SA, SR or CM purpose groups are located above another firecell unprotected areas in the external walls of the firecells shall be separated by no less than:
  (a) 2.5 m where any parts of the unprotected areas are vertically aligned above one another, or
  (b) 900 mm where the unprotected areas on one level are horizontally offset from those on the other level.

- C3/AS1 Paragraph 4.4.7 where the separation requirement of Paragraph 4.4.6 is not satisfied, an apron shall be provided between the lower unprotected areas and those in the upper firecell.

  The apron shall:

  (a) Project horizontally no less than 600 mm from the face the face of the building.

  (b) Continue no less than 600 mm beyond the outer corners of the unprotected area, and

  (c) Have a FRR of no less than that of the floor between the upper and lower firecells.

Applicant disputed the requirement for providing such spandrel or apron. The applicant didn't know the reasons for the spandrel or apron requirements. The applicant's point of dispute was that the all three floors are to be used by one family as household after hours and as a business activity during normal working hours.

The TA disagreed on the grounds that Acceptable Solution required spandrel or aprons to be provided in order to comply with Building Regulations 1992. Clause C3.3.2 in the Regulation states that fire separation shall be provided within buildings to avoid spread of fire and smoke to other firecells, spaces intended for sleeping and household units within the same building.

Acceptable solution extracted the vertical flame spread principle from Igor-Oleszkiewicz(1991). The reason for providing the vertical separation is because the area of openings in lower floor firecell will radiate or project flame from these openings. As a result, the radiation from the projected flame will ignite the upper floor fire cell when the fire is in full-blown.

Alternative method of achieving the same degree of protection as required by Acceptable Solution was also discussed :

a) Providing drenchers –The problem is that no two fire engineers in New Zealand can agree to the type of drenchers required to suppress this type of flame projection.

b) In the BIA's working committee's report to BIA, it did not conclude drenchers to be an Acceptable Solution for achieving compliance for vertical fire spread.

c) If the owner shifted the sleeping area to first floor and use the top as an office, he/she then did not have to provide apron or spandrel.

4.7 Residential Community Care Accommodation

4.7.1 Background

Traditionally, New Zealand was a fully committed social welfare state. The funding was largely coming from tax. The tax system in the old day was very high. The ordinary tax for a person with an average wage would be around 35% to 40%. The higher wage earners would pay 50% to 70% when exceeding certain limits of earnings.

Large portions of tax collected would be distributed to provide free education, hospitalization, and institutions of all kinds and unemployment benefit.

As time goes by, the constant change of the social and economical structure of the country has greatly altered the system. The Government found itself having to cut back funding to a lot of welfare organisations.
In many institutions for people with mental disabilities were being victimized. One by one the wards for the mental disabled around the country were being closed down. Subsequently, those people were being released into the community creating a social and psychological health hazard. Family and relatives took in a few fortunate ones, whereas the majority of them would live among the community with minimum assistance.

Because of the problem, the Government has recently started to provide funding for private organisations who are willing to nurture and train these people, so that the hazard to these individuals and the community can be minimised. Suddenly it is becoming a big business to care for them. The caregiver is generally known as a community service providers.

There are no guideline or regulations provided for this kind of accommodation in the existing Approved Document. Therefore, TAs and designers are in disarrayed as to how a building consent can be best handled without causing major disputes and confusion among parties concerned.

Basically, when dealing with this type of occupancy, the primary concern is the state of mental disabilities of the occupants. The degree of awareness in time of fire for the occupants is the key to the degree of the fire safety required to be provided.

4.7.2 The Fire Safety Approved Document Revision

The "Draft" revision offers flexibility in dealing with this kind of accommodation. It indicates that the purpose group could range from SC purpose group (the most stringent requirement where fire rating of individual rooms, sprinklers and smoke detectors are required) to SH purpose group where no fire safety precautions are required at all.

The "Draft" revision suggests that the TA when granting a building consent shall determine the appropriate purpose group and may base its decision on a written statement from the community service provider.

The statement should include evidence to demonstrate that the means of escape from fire to be addressed as the following by the BIA (1999):

- Means of escape according to the associated purpose group.
- Means of escape according to Fire Safety Precaution in the Fire Safety Annex Table 1B.
- Size of escape routes and required FRRs.

The statement from the community service provider shall take account of:

a) Perceptual abilities of the occupants (sight and hearing).

b) Cognitive and volitional abilities (mental impairment).

c) Ambulatory abilities (physical disabilities).

d) The number of people with disabilities and the mix of disabilities within the group.

e) The assistance those occupants can give one another.

f) Any other relevant details such as the degree of oversight given by the service provider.

Comment:

1. *The presence of people with disabilities does not automatically necessitate a classification into purpose group SC. For example, within a retirement village elderly people with disabilities may initially reside in SR or SH accommodation and later move to SC accommodation should their disabilities become more severe.*
2. *Many people with disabilities are able to evacuate a building as quickly as others having no disabilities. It is unnecessary to impose additional safety requirements in such cases.*
3. *Territorial authorities are expected to give due recognition to the professional skill and judgement of community service providers, in assessing the ability of building occupants to escape from fire.*
4. *When accepting a statement from the community service provider, the TA is entitled to make that statement one of the conditions of the building consent.*

EXAMPLE 4.20

A well-known fire consultant in New Zealand presented this fire report as part of a building consent application.

Accommodation for Community Care

Purpose of Work:

To convert a five bedrooms residential dwelling (SH purpose group) into a community care accommodation. (SA purpose group).

Fire safety proposed by the designer

- Installations of a hard-wired smoke detection system throughout the dwelling.
- Installation of a fire extinguisher.
- Means of escape comply with NZBC.
- Surface finishes requirement to comply with

Queries by TA

1. Please provide a statement for the community service provider to substantiate that the occupants in the dwelling entitle the dwelling to be classified as SA purpose group.
2. Please show how you achieve compliance with the following clauses:
   C2/AS1 Clause 4.2.2 – requires safe path from individual rooms to the final exit.
   C3/AS Clause 2.9.1 – Purpose group SA shall be separated from other purpose groups by fire separations, and each SA sleeping area shall be a separate firecell. The fire separations shall have a FRR using the F rating in Table B1/6 (Appendix B) or 30/30/30 whichever is the greater.
   *Comment on these two questions was asked because the designer did not provide fire separation for each individual room and amenities. He interpreted that the whole dwelling was **a suite,** thus making the same mistake in interpretation as the designer in the example 10.*
3. Please provide an amended plan clearly showing the necessary fire rating to bedrooms and facilities for the dwelling. (Comment – This is the most frequently asked question in fire and egress report review).
4. The hard-wired smoke detection system is not complied with the code, please provide proper detection system to comply with NZS 4561 Alarm Code.

Conclusion

After a lengthy discussion and correspondences with the TA and the designer, the community service provider decided to limit the type of occupants to fit in the criteria of a SH purpose group. A statement from the community service provider had been signed in front of a solicitor and submitted to the TA for approval. The content of the letter qualified the dwelling to a classification of SH purpose group. No specific fire safety system was necessary under this purpose group and a building consent was issued subjecting the conditions of the statement. Shall the conditions of the occupants deviate from the stated conditions, the dwelling will result in a 'change of use', with a new assessment is required in order to achieve compliance.

CHAPTER 5
PERFORMANCE BASED DESIGN PHILOSOPHY

5.0 Introduction

This chapter describes and questions the validity of the t^2 fires and the response time adopted by the specific fire engineering designers for 'alternative solutions'.

5.1 Background

Since the legislation of the Building Act 1991 and New Zealand Building Code 1992 in 1993, the fire engineering design philosophy has taken a complete change in direction. The days of the old ways of doing thing are over, and is replaced by new ways namely the 'Acceptable Solution' published by the BIA using performance-based prescriptive rules and the 'alternative solutions' using specific fire engineering design principles. Both of the methods are based on the objective, functional requirement and performance criteria in the New Zealand Building Code established by the First Schedule of the Building Regulations 1992.

- **Acceptable Solution**

The fundamental basis for means of escape according to 'Acceptable Solution' is to provide sufficient time, commencing from the moment when the occupants perceive the effects of a building fire, to move to a point of safety where they are no longer in danger of being threatened.

A summary of the paper received from John McGregor of the BIA by Branz is presented in the following. The 2½ minutes is the generally accepted as a maximum time for occupants to escape quickly without being overcome by smoke or have their egress exits being blocked by fire. The Building Regulations of England and Scotland clearly used this figure as a basis. This 2½ minutes is based on an alternative path being available. Where only one path is available a 1-minute escape time should apply (SR 1988). The time factor is then translated into distance depending on the Fire Hazard Category. For example, WL light fire hazard category would have an allowable open path of 60m and a death open path of 24m. Whereas for a WD high hazard category would have a total open path of 20m and a dead end open path of 8m. The ratio of the total open path and dead end open path always equal to 2½ times. The US General Services Administration nominates ½ minute, rather 2½ minutes adopted in UK. If the ½ minute is to be translated into distance, it will means that the allowable design time for escape has been cut down by 5 times. It is thought that the allowable short escape time may be the reason the USA has the worst fire death in the developed world.

The means of escape in the 'Acceptable Solution' has not considered human behaviour. The aspect of human response is just as important as any other aspects of the fire engineering design.

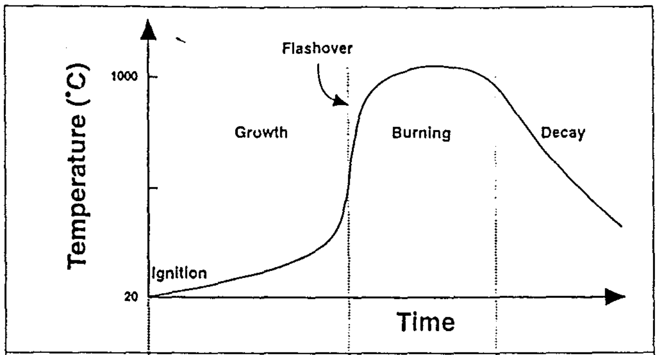
- **Alternative Solutions**

The author is concerned over designers literally taking 'equivalency' to the Acceptable Solution for means of escape when specific engineering design was used for the analysis. This is firstly because the designers do not know and understand the history of the Acceptable Solution, and secondly the human behaviour in fire engineering is considered to be too difficult to quantify. The subject was only first taught at University of Canterbury New Zealand in 1998, and it is still relatively new to most of the designers. Consequently, most designers opted for an easy way out deciding to use a time of 30 seconds to make an decision and 30 seconds to investigate with a margin of safety. The original of the assumption is not known.

5.2 How are the designers applied 'alternative solutions'

The development of fire can be best express from the typical fire development curve shown in Figure 5.1. General Fire Growth Curve.

Fire can occur from one of the three different ways - pilot ignition, spontaneous ignition and spontaneous combustion. Once the fire starts, it will begin to develop according to the geometry of the building, type of fuel and the ventilation of the building available. If there are enough fuel and oxygen in the surrounding, the fire will continue to growth until flashover. Then the flame would reach a steady heat release rate (HRR), until approximately 80% of the fuel are burned off, the flame will start to decay.



Stage	Growth	Burning	Decay
Fire behaviour	Fuel controlled	Ventilation-controlled	Fuel-controlled
Human behaviour	Escape	Death	
Detection	Smoke detectors Heat detectors	External smoke and flame	
Active control	Extinguish by hand, sprinklers or Fire Service. Smoke control	Control by Fire Service	
Passive control	Flammability, surface spread of flame	Fire resistance, containment, collapse	

Figure 5.1: General Fire Growth Curve

(Buchanan, A.H., 1994(a))

The five major design criteria below are generally being considered by specific engineering designers.

1) Radiation to the boundary - The 'Acceptable Solution' Fire Safety Annex Table C3, FIRECALC by CSIRO (1993) now known as FIREWIND are used to give the calculated solutions. Strictly speaking, Table C3 should not be used, because it is not safe. The 'draft' of 'Approved Document Revision' (1999) has offered a much safer solution by replacing Table C3 with a completely new tables formulated by the Approved Document writers. The limitation of radiant flux one metre over the boundary are used based on different fire hazard categories which we had discussed in Chapter 4 example 4.2. However, the 'draft' has also not taken flame projection into consideration, therefore the safety of the building also being compromised.

2) Structural stability – Regarding to structure walls stability at boundary, the columns, beams and internal structural stability, the verification methods are available in Structure Design For Fire (Buchanan 1999) and Design of Steel Buildings For Fire Emergency Conditions (Clifton 1996).

3) Equivalent fire severity (Generally known as 'S' rating) - Several formulas are available to calculate the 'S' rating, They are CIB formula, Law formula, Eurocode formula, Swedish curves, Eurocode parametric fire and Babbrauskas method. All these methods are clearly shown in Structural Design For Fire (Buchanan 1999).

4) Fire scenarios – This is one of the most important design aspects of the fire engineering design criteria, and yet almost all designers used the unrealistic t^2 fires to represent the real fire scenarios.

5) Means of escape – In the means of escape analysis, one of the t^2 fire was always used for determined the layer of smoke descending from ceiling until a critical level of 1.5 to 2.0 metres above the floor was reached.

The Fire Engineering Design Guide by Buchanan (1994) recommended tenability limit noted below are used by all specific designers as the design criteria:

- Convective heat > 65^0 C
- Smoke obscuration > 2m (ie. Optical density > 0.5m)
- Toxicity for 30minutes

CO not > 1400ppm (small children incapacitated in half the time).

HCN not > 12%

CO not > 5%

Radiative Heat – The radiant flux from the upper layer should not exceed 2.5 kw/m^2 at head height (this corresponds to an upper gas layer temperature of approximately 200^0C). Above this, the tolerance time is less than 20 seconds.

The above limits for convective heat, smoke obscuration and toxicity apply to the lower layer if the height of the smoke layer interface at floor level is greater than 1.5 metres (the approximate nose height of a standing adult), otherwise the limits apply to the upper layer results. Computer software such as FPETOOLS, FIRECALC, and C-FAST are used to produce the upper layer results. The choice of a fire model is a critical factor.

Evacuation time and time for conditions to become life threatening are both measured from the time of ignition. Evacuation time t_{ev} is given by:

$t_{ev} = t_d + t_a + t_o + t_I + t_t$

with a safety factor of 2 generally applies to the formula. Therefore, the design criteria becomes

$2 \times t_{ev} < t_{it}$

where

t_d is the time from ignition until detection of the fire (by a building occupant or by an automatic detection system)

t_a is the time from detection until an alarm is sounded

t_o is the time from alarm until the time occupants make a decision to respond

t_i is the time for occupants to investigate the fire, collect belongings, fight the fire

t_t is the travel time, being the actual time required to traverse the escape route until a place of safety is reached, including way-finding and queuing time if applicable.

Computer software HAZARD1, EVACNET +, FPETOOL and FIRECALC and others are available for calculating the travel time. FPETOOL, FIRECALC and simple hand calculations are widely used to calculate the t_t value. No design use HAZARD 1 and EVACNET +.

The t^2 fires and the response time ($t_o + t_i$) in the means of escape are the two main design criteria of the performance based design philosophy of this project the author wish to elaborate. The other three design criteria are very much of the verification methods.

5.3 t^2 Fires

All fire engineering designers of the specific fire design for the past building consent submittals adopted one of the t^2 fires to establish the smoke layer for tenability criteria applying to means of escape. There are four idealised t^2 fires 'slow', 'medium,' 'fast,' and 'ultrafast.' Most designers perceive that any of the real fire can match up to one of the four t^2 fires above. This is far from reality.

The summary of the comments from Babrauskas(1996) in team of t^2 fires in their usefulness in fire design are at the following:

- The t^2 fires initiated in the early 1970s primarily for the studies of detectors. A detector will alarm with a heat release rate of less 100 kw. Therefore, the t^2 fires worked reasonably well. It was subsequently popularised when it became part of the standard NFPA 72. The philosophy of the 'Mighty t^2' creep into the hearts of many designers.
- The t^2 fires have been extrapolated to entirely unrealistic sizes as indicated from the Figure 5.2 extracted from FSE-based building codes. The graph goes up to 30 megawatts. Whereas in the real world, there are few fires whose HRR ever be greater than 3-5 MW.

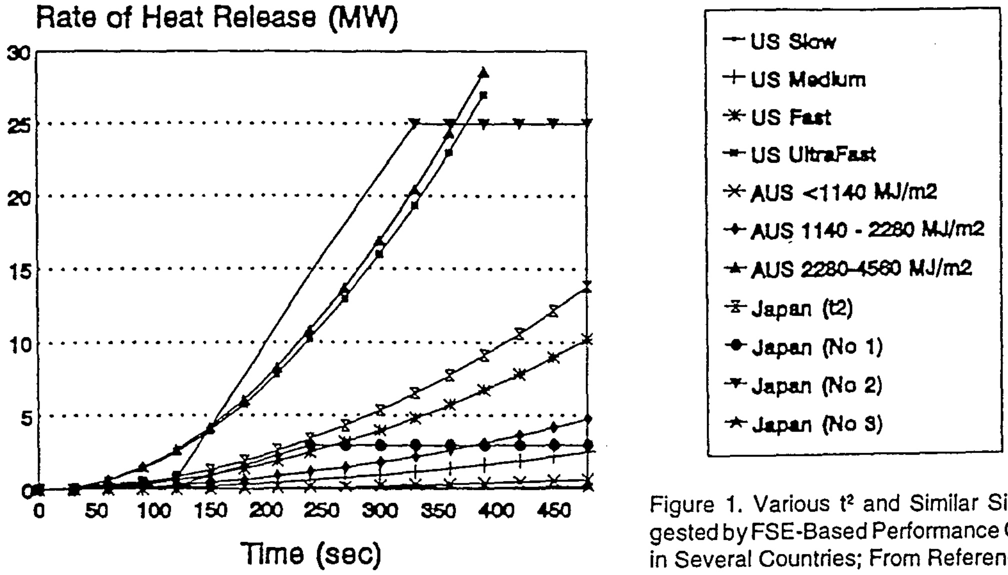


Figure 1. Various t² and Similar Simplified Fires, as Suggested by FSE-Based Performance Codes Being Developed in Several Countries; From Reference 1.

Figure 5.2: Rate of heat release(MW)

(Babrauskas, V., 1996)

- Equally questionable is the philosophy that the t^2 fires can be selected by the designers to match up any real fire scenario. From Figure 5.3, the examples of the HRR of three different chairs along with the t^2 curves of NFPA 72, we can easily see that the t^2 fires are fall short of being useful. There is also no engineering method, which could produce such schematic fire curves to represent real fires. In a desperate measure, we opted for '*a fire to play with is better than no fire*'.

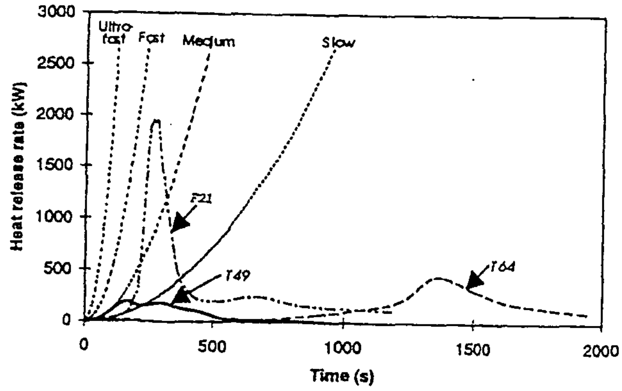


Figure 2. Some HRR Curves For Actual Furniture Items 33, Compared to The t^2 Curves of NFPA 72.

- The peak HRR, which is often the most important fire hazard parameter, is treated as unimportant in schematic t^2 analysis.

Custer et al(1997) expressed the same concerned as Babrauskas, so where do we go from here?

5.4 Means of escape

Although the performance-based engineering design and performance-based prescriptive code are both based on the same requirements, they are far from identical.

- In the 'Acceptable Solution' performance-based prescriptive code, the code writers set the 'minimum' objectives, functional requirement and performance. In this case, the code writers are essentially qualifying and partially quantifying the level of risk acceptable to society. The code writers would also take into consideration that according to the Building Act Section 6-3 due regard could be given to national economic while establishing the Acceptable Solution. Subsequently, some of the Acceptable Solution may be unacceptable in a particular situation whereas it might be quite acceptable on another situation. We had already discussed about the vertical and horizontal flame spread in regard to their significance impact on the creditability of the Approved Document. However, the most significant different in philosophy would be the means of escape between the 'Acceptable Solution' and the 'alternatives solutions'.

- Acceptable Solution

The summary from Branz Study Report(1988) is represented as the following. The fundamental basis for means of escape according to 'Acceptable Solution' is to provide sufficient time, commencing from the moment when the occupants perceive the effects of a building fire, to move to a point of safety where they are no longer in danger of being threatened. 2½ minutes is the generally accepted as a maximum time for occupants to escape quickly without being overcome by smoke or have their egress exits being blocked by fire. The Building Regulations of England and Scotland clearly used this figure as a basis. This 2½ minutes is based on an alternative path being available. Where only one path is available a 1-minute escape time should apply (SR 1988). The time factor is then translated into distance depending on the Fire Hazard Category. For example, from C2/AS1 Table3, the WL light fire hazard category would have an allowable open path of 60m and a death open path of 24m. Whereas a WD high hazard category would have a total open path of 20m and a dead end open path of 8m. The ratio of the total open path and dead end open path always equal to 2½ times. The US General Services Administration nominates ½ minute, rather 2½ minutes adopted in UK. This will mean that the maximum allowable escape time has been cut short in 5 folds in USA. It is thought that this allowable short escape time has made the fire death in USA the worst in the developed world. The means of escape in the 'Acceptable Solution' has not considered human behaviour. The aspect of human response is just as important as any other aspects of the fire engineering design.

- Alternative Solutions

The author is concerned over some designers literally taking the 'equivalency' to Acceptable Solution for means of escape when specific engineering design was used for the analysis. This is firstly because human behaviour in fire engineering was only first taught at the University of Canterbury New Zealand in 1998, and secondly it is considered to be too difficult to quantify. Subsequently, most designer opted for an easy way out deciding to use a time of *30 seconds to make a decision and 30 seconds to investigate, with a margin of safety and out come an instant philosophy.* It is for this reason the author wishes to concentrate more on the philosophy of human behaviour in egress analysis.

5.5 Response Time

The aim of this chapter is to investigate one of the most important aspects and yet the most neglected scenario by almost all fire engineers in Fire Safety Design – the occupant response time for fire evacuation.

By some background research on past fire statistics and data on humans escape behavior in fires and evacuations, we might be able to obtain a better understanding and some guide lines in relating to the occupant response time in fire safety design from the summary below:
The predominant emphasis over the past 20 years in fire safety design is on the nature of the fire and smoke management, fire protection and risk assessment, but none whatsoever on the relationship between people, buildings and fire. As a result, fire protection engineers are unaccustomed to considering the factors that occurs before people actually begin to evacuate a building.

The New Zealand Building Code 1992 does not address this issue, but simply assumed that as soon as the alarm is sounded people would roll like ball bearings towards the egress exits by the shortest route without considering any human behavioral factors.

Many fire engineers in performance based design would simply opte for the easy way out by adopting an assumed response time with a margin of safety which has no scientific basis in fire engineering.

Researchers like Bryan(1995),Wood(1972), Latane et al (1968). Ramchandran et al (1982) produced many behavioural statistics on human response and evacuation sequences, but never actually come out with a method of calculating response time during fire evacuation.

Dr Jonathan Sime(1994) with his 20 years of research and statistical data has gone a step further by deriving a system whereby the occupants response time can be scientifically calculated with a fair degree of confidence.

The write-up and summary of the human behavior from paragraph 5-6 to 5-15 are based on the studies of Custer et al (1997), Bryan (1995) and Sime(1994).

5.6 Awareness of Cues

While the human behaviour of occupants in fire has been studied extensively over the last 40 years, the data has not always found its way into codes and standards. In the past the emphasis has been on the movement phase of the evacuation process. This has sometimes resulted in fire engineers ignoring what occurs before the occupants start to evacuate the building and then modeling the movement of occupants as flowing water through pipes.

The following is a proposal of how the established human behaviour in fire concepts can be utilised in the design process of new buildings.
The objective stated in Clause C2 of the New Zealand Building Code 1991 is to "Safeguard people from injury or illness from a fire while escaping to a safe place."

5.7 Models of Human Behaviour during Fire

Models of human behaviour during fire are complex and dynamic but fire engineers should draw on some of the extensive research carried out over the last 40 years, such as Project People I and II (Bryan 1995) in trying to understand and model the behaviour.
People use the following six basic techniques to decide what to do in a fire they are:

- **Recognition** is the process where the occupants receive the ambiguous fire cues. The individual recognises the threat cues in terms of the most probable occurrence. Typically this is related to a prior personal experience with an optimistic outcome. A favourable outcome maybe due to a persons invulnerability to risk.
  Threat recognition is recognised as an important issue in fire engineering, since evacuation, fighting the fire or alerting others and the Fire Service may be delayed if the occupant doesn't interpret the cues. In some public and social groups a large quantity of smoke or a threatening situation is required before the occupants without previous fire experience perceive a threatening situation, the Arundel Park Fire is a classic example of this.

- **Validation** is the process of the occupant attempting to verify the initial perception of the fire cue, primarily by seeking verbal reassurance of the minor and insignificant character of the fire situation.

  Often additional information will be sought when the cues are ambiguous. The occupant is aware something has happened but they are not sure what. A study by Killian (1956) found 85 of the 135 people surveyed about an explosion at their plant obtained information about the situation from others either in person or by phone.

- **Definition** is the process where people try to structure and quantify what they know about the fire threat. Defining for example how much smoke they smell, how hot is it, or how many flames they see and where is the fire in relation to their position. This helps them relate a threat to their own situation.

  The occupants are typically under severe stress and anxiety before they define the initial ambiguous cues with structure for the situation. Often they realise that the incident requires structure and interpretation before the cues can be defined. The role concept also is a critical factor in this stage of the process.

- **Evaluation** is the process where people decide whether to fight or flight to reduce danger. The decision often happens within seconds and again under great stress and threat, remembering that while the evaluation may only be seconds this can be significant in terms of the generation and propagation of the fire. The actions of others greatly influence the evaluation process.

  The occupants "perceived time" available to evacuate is based on their estimation of the fire threat. Again this emphasises the importance of quality and informative cues.

  People evacuate an escape or defence procedure based on; the location of the exit relative to their position, the location of others at risk, the perceived untenable effects and overt behaviour response of others. During the evaluation process others can easily effect the individual. This may result in mass adaptive or non-adaptive behaviour of the population.

During the process individuals who are familiar with the building, the situation and in a familiar role may experience less stress and will probably behave in an adaptive manner rather than the individual in unfamiliar surroundings.

- **Commitment** is the process where the occupants act on their decision during the evaluation process. This is completed, partially completed or not completed. If not completed the individual enters a process of reassessment and commitment. If completed successfully the anxiety decreases even if the fire severity has increased.

- **Reassessment** process is probably the most stressful because of the failure of the individuals previous attempts to escape or control the fire. If successive failures are encountered, the individual becomes more frustrated, anxiety increases, and the probability of success decreases. In the Arundel Park fire a number of people selected the windows as a secondary means of escape.

5.8 Four Socio-Psycholgical Concepts Applied to Human Behaviour During Fires

Another way of trying to understand how people act in fires is to consider four Socio-Psychological concepts being: avoidance, commitment, affiliation and role.

- **Avoidance** is where people feel they can protect themselves by denying unpleasant situations. Avoidance explains why people delay recognising the threat, this wastes precious time and reassuring themselves with benign explanations.

- **Commitment** is where people are committed to their activity, in a line at a shop, gambling, or working when they receive the first cues. Again people may delay due to the commitment to continue what they are doing, the Dupant Hotel and Casino fire in Puerto Rico are good examples, the punters stayed on the gambling floor even with the dramatic fire cues.

- **Affiliation** can be another cause of delayed evacuation. This can simply be explained by a family waiting for everyone to get ready before leaving. Once they start to evacuate the slowest member will then govern their speed.

- **Role** is where the occupant's status or role in the building helps determine their response. Occupants unfamiliar with the building, such as visitors, will be more passive than residents or employees of the building. As discussed those in a familiar situation will tend to spend longer validating and recognising the threat. Employees may wait for an instruction from a supervisor.

  As found in the Project People II Health as doctors wouldn't normally attend fire training sessions they could throw a spanner into the works during a real fire emergency. Also during Ballantynes fire office staff allegedly were told to load documents into the safe by a manager, this meant that they didn't have a chance to escape.

5.9 Alarm Signals

Two important fire design considerations are firstly how are the occupants alerted and secondly how will the Fire Service be notified. People will not react to a threat unless they understand what is going on.

The occupants are alerted to a fire in one of three ways. Firstly by self-identification of a fire cue, such as heat, smoke, flame or noise. Secondly by self-identification of an equipment generated alarm, i.e. a fire alarm system, voice alarm or an individual smoke detector. Finally others can notify them. The Project People I Residential study found this to be as high as 35%.
But typically fire design assumes people will be alerted by an equipment-generated signal. The New Zealand Building Code assumes that the occupants will hear the signal, recognise it as a fire alarm, accept it as true and begin to evacuate. This shouldn't be taken for granted in the design process. Serious consideration needs to be given to the documented human behaviour in relation to fire concepts.

Most buildings utilise some form of audible alarm, high-rise or other buildings with very high occupant loads often are required to incorporate a voice communication system in the fire safety features. Typically people don't respond well to non-voice systems. Proulx(1991) found this in her study of the London Underground.

Part of the problem seems to be that people are skeptical about of a fire alarm and whether or not is it real or just another false alarm. Often the decision to leave may be based on the occupant's experience with the fire alarms in the building. If they decide not to leave this will delay them recognising a potentially life threatening situation.

These factors (alarm type and alarm reliability) need to be taken into account when selecting the best way to alert the building occupants.

Many people do not hear nor comprehend the alarm signal. This has been studied extensively but the focus seems to be on sound attenuation, the SFPE handbook features a number of papers on sound through various building materials. In addition to sound attenuation the signal frequency and signal mode needs to be considered. High frequencies are readily blocked but lower frequencies may pass through walls and other barriers. Some studies have found that a good response is obtained with rapid pulsing signals of a low frequency.

The designer needs to consider the condition of the building occupants, i.e. do they have hearing impairments? are they on medication? are they elderly?. The level of ambient sound also needs to be considered, typically the alarm should be at least 15 dBa above the ambient sound level.

The position of the alarm may also be important, for example an extremely loud sounder in the exitways designed to penetrate walls may prevent communication between the occupants, which as the studies have found is common and an important means of notifying other occupants.

5.10 Threat Recognition

The process of threat recognition is defined when the occupant senses and understands an alert or alarm signal, or fire cue, the next step is a process of interpreting this alarm and deciding if the alarm or cue is a threat.

In many cases the transition time between awareness of the fire cues and recognising the threat maybe seconds, particularly if the occupant is in the same room as the fire. In other cases, particularly when the occupant doesn't know where the fire is or even if there is a fire there might be a significant gap between receiving the cue and perceiving it as a threat.

The number of false alarms the building has had, or the "Cry Wolf" syndrome, may be extremely important when people are trying to perceive a threat. While occupants are trying to validate a threat valuable time is being wasted. Studies have indicated that delayed threat recognition commonly occurs and this must be considered in the fire protection design.

In their study of evacuation drills from a London Underground Station, Proulx and Syme(1991) found the use of directive public announcements with an alerting alarm was the most effective for immediate effective evacuation. When only an alarm was used 76% thought it was not an emergency compared with 54% with the alarm and public announcements.

The recognition of ambiguous fire cues can be inhibited by the presence of others. Latane et al(1968) found in their smoke experiments with college students that while students along reported the smoke 75% of the time, when the students were in groups of three or more the smoke was only reported 38% of the time. This indicated the inhibiting influence of others that individuals may accept as being imposed upon their behaviour in public places. If the individuals remain passive, this inhibiting social response is thought to reinforce the non-emergency interpretation for the individual. The tendency to mimic the interpretation of cues and behaviour responses from others has frequently happened in fire incidents in restaurants, hotels and other areas of public assembly.

5.11 The Myth of Panic

The media, television and movies have shown us a link between fires and panic, studies of real fires however have found that panic or non-adaptive behaviour rarely occurs. Panic was defined by Bryan(1958) as " a sudden and excessive feeling of alarm or fear, usually affecting a body of persons, originating in some real danger, vaguely apprehended, and leading to extravagant and injudicious efforts to secure safety."

Four elements were identified by Keating(1982) as essential to panic behaviour but argued that one or more is normally absent from most fire evacuations. They are characterised by a hope for escape even with closing escape routes, contagious behaviour or following the leader, aggressive concern by the occupants for their own safety as opposed to others and finally irrational or illogical response to the fire.

As discussed earlier if there is inadequate or ambiguous information about the location and size of the fire people may act inappropriately but rarely panic or behave irrationally.

5.12 Evacuation Behaviour

In an ideal world, all occupants begin to evacuate as soon as a fire alarm sounds, this is assumed in many building codes. In the real world the actions may be very different, people aren't ball bearings that roll toward the exit.

Canadian research into human behaviour during evacuation drills found that it took people between 30seconds to 14 minutes to start evacuating with most starting 3 minute after the alarm was audible throughout the building. Some of the delays where attributed to people not hearing the alarm and not recognising the threat of fire. In all buildings other delays occurred while people looked in the corridors, looked for their kids, got dressed and gathered valuables.

They also found that when the sounder was only located in the common corridors 25% of the occupants failed to hear the alarm. The occupants were only alerted when the fire department knocked on their door. Where the audible alarm was poor the average time to evacuate was 9:04 minutes, with the time to start ranging from one minute to 24 minutes. In three buildings where the alarm was judged loud enough by 80% of the occupants the mean evacuation time was 2:54 minutes. *The time to start varied from 24 seconds to 14 minutes.*

The research also found that most people evacuated in groups with the speed of the group being governed by the slowest member. *Gender, age and mobility actually were found to have little impact on the evacuation time. For example it was found that older people moved slower but started moving earlier. As expected people also used exitways that were familiar.*

Although the Canadian Research was done in the absence of a fire threat there was some valuable human behaviour in fire concepts that should be considered when designing a fire protection system.

5.13 Egress Design

There are basically two approaches being taken in the egress design as described by Sime(1994):

- Model A - the traditional fire code and engineering model, equates people with static or dynamic non thinking objects in which the time required for escape is assumed to be determined primarily by the fire scenario, the object risk, occupant loads and the physical accessibility of the means of escape.
- Model B – The environmental psychology model, assumes that the time for escape is depending upon the occupant physiological and psychological processes to filter through, the time it takes people to start to move and move, the warning system and perceived risk. Model B selects most meaningful response, consider responses for which we have or gather data from literature, research results and statistics.

5.14 Chapter 9 Fire Engineering Design Guide

The Fire Engineering Design Guide is considered to be the textbook by Fire Engineers in New Zealand, undertaking specific fire engineering design solutions. It has all the fundamental ingredients and has been well prepared and presented with helpful design examples. However, 'Means of Escape' in Chapter 9 in its present, is probably closer to traditional Egress Model A.

The calculation time to evacuate a space (tev) is based on the sum of five variables, detection (td), alarm activation(ta), occupant response(to), investigate(ti) and travel times(t_t).

$$t_{ev} = t_d + ta + to + ti + t_t$$

The above is then multiplied by a safety factor (SF = typically 2) and checked against the available time before conditions become untenable (t_{lt}). Evacuation time and time for conditions to become life- threatening are both measured from the time of ignition (Buchanan 1994).

The Guide does not present any meaningful data for to and ti for various occupant scenarios, instead typical values of 30 seconds for each are used in the example. The assumption would probably be acceptable for a high ceiling building with small occupant densities where smoke filling times are prolonged.

For lower ceiling and high densities building with various compartments or sleeping purpose building, the assumption could be unsafe. Also as highlighted in the Canadian Research Apartment earlier even with a factor of safety the calculated evacuation time may be by a large magnitude.

It is considered that the term(to + ti) or the occupant response time may be more appropriate adopted with a value time based on research of the human behaviour in fires for the type of occupancy and also importantly consider the alarm system that will be installed. A factor of factor 2 could then be applied only to the travel time t_t with the new formula becoming

$$t_{ev} = t_d + t_a + t_{res} + 2t_t$$

Dr. Jonathan Sime's Response Time (t_{res}) calculation is being presented in Appendix C. His research is based upon a combination of human behaviour for various purpose groups, environments and types of alarm being installed in the building to come up with a more realistic response time than the (30+30) sec respond time adopted as a 'Gospel' truth for most designers in New Zealand. The performance- based Australia

Code(1996) has derived the response time based on Dr. Johnathan's philosophy, why can't New Zealand?

5.15 Summary

In summary as a fire engineer designing a building protection system a number of important established human behaviour in fire concepts need to be considered. Escape route systems should be keep as simple as possible. Corridors that often change direction, like a maze, should be avoided, along with a number of doors, which might prevent the flow of information. If the exitways are simple, easily located it will avoid an increase in stress for the individuals that are not familiar with the building or that particular exit.

- The pre-fire activity should also be considered, e.g. are the occupants likely to be sleeping, if so will the fire alarm wake them. The Canadian Research highlighted the importance of an effective audible alarm i.e. the average time of evacuation was 9.04 and 2.54 minutes, for the poor and the good audible alarms respectively.

- The designer should also ask, will the occupants be familiar with the fire alarm and recognise it as a threat and start to evacuate? If this is unlikely then maybe the alarm could be complemented with public address messages or with visual messages.

- A scenario should be developed based on the location of the occupants considering how they will receive their cues. Consideration can then be given to whether to allow for an interface between behaviour and the fire environments.

- Substantial weight should also be placed on the occupant characteristics; do they know the building? what is their culture, sex, role in the building, degree of ability, how many occupants, past experience, training and population mix?

- Finally as the research of human behaviour in fires has found that ambiguous cues lead to increased stress which will reduce the chance of escape from the fire. New buildings fire safety systems should aim to communicate as much information as possible to the occupants about the fire, its location relative to them and the stage of the fire. The occupants should then be told whether to wait, prepare to exit or evacuate by a specified exitways. This will ensure that the objective of the safeguarding people while escaping in New Zealand Code is met.

CHAPTER 6: CONCLUSION & RECOMMENDATIONS

6.0 Conclusion

Based on author's own observation, about 80% of the residential fire related designs and drawings and about 60% of the commercial fire related designs and drawings currently submitted for building consent do not comply with the Building Act 1991 and Building Code 1992 before they are being reviewed. It reflects a very unhealthy situation in the field of fire engineering.

Psalm 139 Verse 13-14 (NIV 1984) king David prayed to The Lord;

For You created my inmost being;

You knit me together in my mother's womb.

I praise You because I am fearfully and wonderfully made;

I know that full well.

This tells us that we are unique. Yet, the protection of life from fire is being treated lightly and even considered to be a 'financial burden' by a majority of building owners. The great *trio philosophy* of the fire safety design criteria included in New Zealand Building Code 1992, with clear statements of **"The Objective, Functional Requirement and Performance"**, has the potential to produce safe buildings, but only if the Building Code is implemented in a knowledgeable and responsible way.

It is concluded that the current problems of the fire engineering during building consent stage are as the followings:

- **Presentation and documentation**

  Most of the fire engineering reports are not well documented and presented. They tend to be buried in the other documents required for building consent.

- **Attitude towards fire and the safety requirement of the Building Code.**

1. **The building owners.** The building owners are more concerned about building security than fire safety. They tend to regard fire safety system as a necessary evil. It is important that building owners should know the liabilities and responsibilities in relating to their safety of their building from fire in order to avoid possible prosecution when things go wrong.
2. **The fire & egress designers** - The fire engineering designers are facing a very difficult assignment because of the some owners attitude. Sometimes, they may even become unethical by misrepresentation of information. in order to please the building owners. Some designers do not differential between the Acceptable Solution , Building Act and Building Code. Due to lack of approved methods in specific design, the designers may include design philosophy or applied personal opinions without any material to back their claim.
3. **Peer reviewers** - Peer reviewers tend to be more fire engineering principle orientated whereas the TAs are more codes orientated. The peer reviewers need to be in unison with both types of design. Because there is a lack of approved methods in specific design, the peer reviewers may include an unsound design philosophy or applied personal opinions without any material to substantiate their claim.
4. **Territory Authority** – Because of the inconsistency of the fire reports and drawings and lack of proper education for most designers, the TAs are facing a mammoth task in advising designer and rectifying their errors. Some times, the TAs may even need to think like a detective in order to do their jobs properly.
5. **Certifiers** – Being the major competitors of the TAs, the certifiers must be vigilant because they are monitored very closely their submitted building consent applications.
6. **Builders** - Builders are generally not familiar with the Building Act, Building Code and Approved Document. They could be very cynical towards fire designers and TAs point of views on fire rating requirements. They must also

be careful when giving advice to any owners in order to avoid unnecessary problems.

- **Integration of fire safety requirements with the drawings**

  The problem of integration between fire safety requirements and drawings has created one of the worst nightmares and frustration for the TA officials. The fire designers tend to rely on the architects/draughtsperson to provide details and they, in term, tend to rely on the fire designers. It becomes a '*Blind following the blind*' syndrome.

- **Familiarity with Approved Documents**

  Lack of familiarity of the Approved Document can lead to dangerous situations in fire safety engineering systems being approved and built by all parties concerned. It can also incur financial loss because of having to change the design after the building or units have been pre-sell due to incorrect design at the beginning.

- **Fire rating at different boundary conditions**

  Far too many designers do not understanding clearly the application for fire ratings at different boundary situations. It could result in major dispute and financial loss for the designers and owners if not done correctly at the initial stage. As a result, the designers could end up in hot water.

- **Residential community care accommodation**

  The Acceptable Solution has no specific rules set out for under this category in the Building Act & NZBC. Therefore, the TAs and designers are totally relied on the guidelines from the BIA draft "Fire Safety Approved Document Revision" (BIA 1999) and to some extent the philosophy of the Fire Service Guidelines for public comment draft "Fire Safety and Evacuation in Health Care Facilities"(1999). Alternatively, an 'alternative solution' can be used to provide a solution.

- **Performance based design philosophy**

  The philosophy of the design t^2 fires and the response time being adopted in the means of escape analysis by almost all specific designers are far from realistic and useful. And yet, many designers use them as if they are the absolute methods. ***Are we playing with fires***?

6.1 Recommendations

From the above conclusions, the recommendations are as the followings:

- Since the Government instigated the building Regulations, it is their responsibility to provide sufficient finance for the Building Industry Authority (BIA), the Society of Fire Protection Engineering (SFPE New Zealand Chapter), and the universities to improve education and training in fire engineering. With new funding available, they can are take on the leading role in educating and nurturing all the players in the field of fire engineering. In this way, an acceptable standard in fire engineering design may gradually be achieved.

- There should be a minimum educational qualification for fire safety designers and reviewers.
- The designers should be made to sign on the working drawings as a token of their approval and responsibility to their projects.
- The t^2 fires should be discouraged, and every effort should be made to encourage research for better ways to establish fire curves close to realistic fire scenarios.
- A realistic and conservative response time should be adopted in order to achieve a safe design for the means of escape.
- Research should be encouraged from the data and statistic available on human behaviour, in order to come up with a more realistic response time. The response time by Sime (1994) should be adopted as a New Zealand response time design criteria because it is based on research data.

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Appendix A: Survey

The following tables give an account of the survey form sent to nine city councils, and a summary of their responses. The survey was conducted by A. H. Buchanan (Buchanan 1999).

Survey Form

These questions apply to all buildings except houses and townhouses. Please consider the changes, which have occurred since the New Zealand Building Code replaced NZS1900 Chapter 5. Circle one number in each line below:

	In your opinion, is there more or less	**Less**		**Same**		**More**
1	Fire safety for the occupants	1	2	3	4	5
2	Property protection for the building owner	1	2	3	4	5
3	Property protection for adjacent owners	1	2	3	4	5
4	Number of sprinkler systems being installed?	1	2	3	4	5
5	Number of smoke alarm systems being installed?	1	2	3	4	5
6	Overall cost of fire protection	1	2	3	4	5
7	Work in processing the consent application	1	2	3	4	5
8	City council staff knowledge about fire behavior in buildings?	1	2	3	4	5
9	Designer knowledge about fire behavior in buildings?	1	2	3	4	5

Please estimate (at the present time)	%
Type of application:	
Percentage of applications based entirely on the Acceptable Solutions	
Percentage of applications with minor changes from the Acceptable Solutions	
Percentage of applications with significant changes from the Acceptable Solutions (ie. an Alternative Solution)	
Total	100

Review of application:

Percentage of applications reviewed y city council staff

Percentage of applications sent out for independent peer review

Total	100

Who prepared the application?

Percentage of applications prepared by main designer (architect, designer, structural engineer)

Percentage of applications prepared by well qualified fire engineering consultant

Percentage of applications prepared by poorly qualified fire engineering consultant.

Total	100

Survey Results

	Type of city:	A	A	A	B	B	B	B	C	C	
	Is there more or less:	(1 = less, 3 = same, 5 = more)									Average
1	Fire safety for the building occupants	3	5	4	4	4	4	4	4	5	4.0
2	Property protection for the building owner	1	2	2	2	2	1	2	4	2	1.7
3	Property protection for adjacent owners	2	2	4	2	3	2	4	4	2	2.7
4	No. of sprinkler systems being installed	4	5	4	4	3	1	4	2	4	3.6
5	Number of smoke alarm systems installed	5	5	4	5	4	4	5	4	5	4.6
6	Overall cost of fire protection	-	4	3	4	4	2	4	4	4	3.5
7	Work in processing the application	5	5	4	5	4	2	4	3	3	4.3
8	TA. staff knowledge about fire behavior	4	5	4	4	3	2	5	3	4	3.9
9	Designer knowledge about fire behavior	4	4	4	4	3	4	3	3	4	3.7
10	*Type of application (percentage):*										
	Based entirely on Acceptable Solutions	70	50	60	60	98	85	95	90	80	74.0
	Minor changes from the Acceptable Solution	25	40	15	20	1	10	2	7	18	16.1
	Significant change	5	10	25	20	1	5	3	3	2	9.9
11	*Review of application (percentage)*										
	Reviewed by T.A staff	95	90	90	50	10	95	95	95	100	75.0
	Independent peer review	5	10	10	50	90	5	5	5	0	25.0
12	*Who prepared the application (percent)*										
	Main designer (architect, structural engineer)	60	55	70	60	98	30	70	30	80	63.3
	Well qualified fire engineering consultant	30	45	25	20	2	50	25	65	5	28.1
	Poorly qualified fire engineering consultant	30	5	5	20	0	20	5	5	15	12.1

A: City with population over 250,000
B: Suburban area of city type A
C: City with population under 250,000

Appendix B: Extract from "The New Zealand Building Code"

CHAPTER 2

CODE REQUIREMENTS

This chapter consists of the performance requirements of the New Zealand Building Code extracted directly from the Building Regulations 1992. Words in italics are defined terms in the Building Code.

Clause C1 — OUTBREAK OF FIRE

OBJECTIVE

C1.1 The objective of this provision is to safeguard people from injury or illness caused by *fire*.

FUNCTIONAL REQUIREMENT

C1.2 In *buildings* fixed appliances using the controlled combustion of solid, liquid or gaseous fuel, shall be installed in a way which reduces the likelihood of *fire*.

PERFORMANCE

C1.3.1 Fixed appliances shall be installed so as to avoid the accumulation of gases within the installation and in *building* spaces, where heat or ignition could cause uncontrolled combustion or explosion.

C1.3.2 Fixed appliances shall be installed in a manner that does not raise the temperature of any *building element* by heat transfer or concentration to a level that would adversely affect its physical or mechanical properties or function.

Clause C2 — MEANS OF ESCAPE

OBJECTIVE

C2.1 The objective of this provision is to:

(a) Safeguard people from injury or illness from a *fire* while escaping to a *safe place*, and

(b) Facilitate *fire* rescue operations.

FUNCTIONAL REQUIREMENT

C2.2 *Buildings* shall be provided with *escape routes* which:

(a) Give people *adequate* time to reach a *safe place* without being overcome by the effects of *fire*, and

(b) Give fire service personnel *adequate* time to undertake rescue operations.

PERFORMANCE

C2.3.1 The number of *open paths* available to each person escaping to an *exitway* or *final exit* shall be appropriate to:

(a) The *travel distance*,

(b) The number of occupants,

(c) The *fire hazard*, and

(d) The *fire safety systems* installed in the *firecell*.

C2.3.2 The number of *exitways* or *final exits* available to each person shall be appropriate to:
- (a) The *open path travel distance*,
- (b) The *building height*,
- (c) The number of occupants,
- (d) The *fire hazard*, and
- (e) The *fire safety systems* installed in the *building*.

C2.3.3 *Escape routes* shall be:
- (a) Of *adequate* size for the number of occupants,
- (b) Free of obstruction in the direction of escape,
- (c) Of length appropriate to the mobility of the people using them,
- (d) Resistant to the spread of *fire* as required by Clause C3 "Spread of Fire",
- (e) Easy to find as required by Clause F8 "Signs",
- (f) Provided with *adequate* illumination as required by Clause F6 "Lighting for Emergency" and
- (g) Easy and safe to use as required by Clause D1.3.3 "Access Routes".

Clause C3 — SPREAD OF FIRE

OBJECTIVE

C3.1 The objective of this provision is to:
- (a) Safeguard people from injury or illness when evacuating a *building* during *fire*,
- (b) Provide protection to fire service personnel during fire fighting operations,
- (c) Protect adjacent *household units* and *other property* from the effects of *fire*,
- (d) Safeguard the environment from adverse effects of *fire*.

FUNCTIONAL REQUIREMENT

C˜ 2 *Buildings* shall be provided with safeguards against *fire* spread so that:
- (a) Occupants have time to escape to a *safe place* without being overcome by the effects of *fire*,
- (b) Firefighters may undertake rescue operations and protect property,
- (c) Adjacenı *household units* and *other property* are protected from damage, and
- (d) Significant quantities of *hazardous substances* are not released to the environment during *fire*.

PERFORMANCE

C3.3.1 Interior surface finishes on walls, floors, ceilings and suspended *building elements*, shall resist the spread of *fire* and limit the generation of toxic gases, smoke and heat, to a degree appropriate to:
- (a) The *travel distance*,
- (b) The number of occupants,
- (c) The *fire hazard*, and
- (d) The active *fire safety systems* installed in the *building*.

C.3.3.2 *Fire separations* shall be provided within *buildings* to avoid the spread of *fire* and smoke to:
- (a) Other *firecells*,
- (b) Spaces intended for sleeping, and
- (c) *Household units* within the same *building* or *adjacent buildings*.

C.3.3.3 Fire separations shall:
- (a) Where openings occur, be provided with *fire resisting closures* to maintain the

integrity of the fire *separations* for an *adequate* time, and
(b) Where penetrations occur, maintain the fire *resistance rating* of the *fire separation.*

C3.3.4 *Concealed spaces* and cavities within *buildings* shall be sealed and subdivided where necessary to inhibit the unseen spread of *fire* and smoke.

C3.3.5 *External walls* and roofs shall have resistance to the spread of *fire*, appropriate to the *fire load* within the *building* and to the proximity of other *household units* and *other property.*

C3.3.6 Automatic fire suppression systems shall be installed where people would otherwise be:
(a) Unlikely to reach a safe place in *adequate* time because of the number of storeys in the *building*,
(b) Required to remain within the *building* without proceeding directly to a *final exit*, or where the *evacuation time* is excessive,
(c) Unlikely to reach a *safe place* due to confinement under institutional care because of mental or physical disability, illness or legal detention, and the *evacuation time* is excessive, or
(d) At high risk due to the *fire load* and *fire hazard* within the *building.*

C3.3.7 Air conditioning and mechanical ventilation systems shall be constructed to avoid circulation of smoke and *fire* between *firecells.*

C3.3.8 Where an automatic smoke control system is installed, it shall be constructed to:
(a) Avoid the spread of *fire* and smoke between *firecells*, and
(b) Protect *escape routes* from smoke until the occupants have reached a *safe place.*

C3.3.9 The *fire safety systems* installed shall facilitate the specific needs of fire service personnel to:
(a) Carry out rescue operations, and
(b) Control the spread of fire.

C3.3.10 Environmental protection systems shall ensure a low probability of *hazardous substances* being released to:
(a) Soils, vegetation or natural waters,
(b) The atmosphere, and
(c) *Sewers* or public *drains.*

Performance C3.3.10 applies only to *buildings* where significant quantities of *hazardous substances* are stored or processed.

Clause C4 — STRUCTURAL STABILITY DURING FIRE

OBJECTIVE

C4.1 The objective of this provision is to:
(a) Safeguard people from injury due to loss of structural stability during *fire*, and
(b) Protect *household units* and *other property* from damage due to structural instability caused by *fire.*

FUNCTIONAL REQUIREMENT

C4.2 *Buildings* shall be constructed to maintain structural stability during *fire* to:
(a) Allow people *adequate* time to evacuate safely,
(b) Allow fire service personnel *adequate* time to undertake rescue and fire fighting

operations, and

(c) Avoid collapse and consequential damage to adjacent *household units* or *other property*.

PERFORMANCE

C4.3.1 Structural elements of *buildings* shall have *fire* resistance appropriate to the function of the elements, the *fire load*, the *fire intensity*, the *fire hazard*, the height of the *buildings* and the *fire* control facilities external to and within them.

C4.3.2 Structural elements shall have a *fire* resistance of no less than that of any element to which they provide support within the same *firecell*.

C4.3.3 Collapse of elements having lesser *fire* resistance shall not cause the consequential collapse of elements required to have a higher *fire* resistance.

Appendix C: Repsonse Time Calculations

ASSESSING OCCUPANT RESPONSE TIME

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Abstract

Research on human behaviour indicates the crucial importance of an adequate public warning system, in reducing the risk from a fire as it evolves in a wide variety of settings (eg Channel Tunnel, underground stations, stadiums, shopping complexes, hotels, hospitals). This paper reviews a procedure for assigning pre-movement times a design value and prioritising occupant response time as a fire engineering system performance criterion. This requires two models of human behaviour to be reconciled. Model A, the traditional fire code and engineering model, equates people with static or dynamic non-thinking objects in which the time required for escape is assumed to be determined primarily by the fire scenario, the objective risk, population size and the physical accessibility of the means of escape. Model B, the environmental psychology model, assumes that the time for escape is characterised by the occupant behaviour scenario, the time it takes people to start to move and move, the warning system, perceived risk and a number of social and psychological parameters. Several occupant response concepts, methods and criteria are considered in relation to the EC Construction Products Directive (1989), Australian draft National Building Fire Safety Systems Code (1991), US NFPA 101M Fire Safety Evaluation System (FSES) (1992) and the draft BSI Fire Safety Engineering Code (1994): fitness of products in use, an occupancy population risk profile, pre-movement time (tpre) measure, occupant movement and wayfinding index. A procedure for assessing tpre in the draft BSI Code is presented. Tpre is derived from a matrix of tpre best (b.p.s.), average (av.p.s.) and worst possible scenarios in response to different types of warning systems (w1 = alarm bell, w2 = nondirective pre-recorded fire warning message, w3 = live directive public address + CCTV). The Tpre av.p.s. is adopted, or the tpre b.p.s. is multiplied by an occupancy response efficiency weighting (Weff) derived from aggregate ratings of a number of tpre parameters defined in the paper. This Tpre adjusted design value for the occupancy is then compared with the benchmark criterion of the tpre av.p.s. = tpre b.p.s. x safety factor of 2. It is concluded that there is a need for fire engineering solutions to be assessed in relation to post-occupancy records of pre-movement and movement response times.

Australia/New Zealand Dec 1994

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4.4 Research of escape behaviour in fires and evacuations suggests that, in addition to means of escape design parameters such as travel distance, number and position of exits and exits widths (see Section 7), the following factors should be used to establish the speed of response of people in different occupancies in an emergency such as a fire:

(A) COMMUNICATIONS: What kind of warning system is in place, ranging from an alarm bell (system), informative warning visual displays, a 'non-directive' (prerecorded) public announcements (P.A.) and/or a live 'directive' P.A. system from a Control Room (using CCTV)?

(B) ALERTNESS : How likely is it that people will be awake or asleep?

(C) MOBILITY: What are the sensory (eg hearing, vision) and mobility abilities and disabilities of the range of people likely to be?

(D) SOCIAL AFFILIATION: Are individuals most likely to be alone, separated from or in a primary social group (eg a family) in the setting when first alerted?

(E) ROLE: What is the ratio of public to staff in the setting?

(F) POSITION: How likely is it that people in the setting will be lying down, sitting, standing or moving at the time when first alerted?

(G) COMMITMENT: To what degree is the setting characterised by activities which people will be committed to finish (such as queuing to obtain a ticket) before recognising the need to evacuate?

(H) FOCAL POINT: To what degree does the setting have a particular focal point in terms of the direction of attention (eg a theatre)?

In addition, there are a number of aspects of the occupancy which will also influence the time expended in movement during the early stages of a fire, the pattern of wayfinding and escape behaviour *(expand as a section on wayfinding design criteria elsewhere)*

(I) FAMILIARITY: How familiar are the majority of people likely to be with different areas, entry and exit routes from the setting?

(J) POPULATION DENSITY: What are the maximum numbers of people permitted in the setting and how are they likely to be distributed throughout the setting?

(K) VISUAL ACCESS: How visually accessible are the alternative exit routes from the setting?

(M) ENCLOSURE: How enclosed or open is the setting?

(N) COMPLEXITY How complex or simple is the setting?

4.5 The greater the number of asterisks in the matrix defined by Table 1, the more likely that each of these factors will be present in a particular occupancy type and people will be slow to start to move in an optimum direction in terms of a fire's growth and alternative escape routes. The asterisks in Table 1 are illustrative, rather than a definition of the characteristics of an individual occupancy. To determine the likely contribution of each factor to evacuation times, an occupancy needs to be assessed individually as part of the fire safety engineering assessment procedure (See Section 6).

Table 2 A matrix of baseline estimates of $t1$ (time to start to move) in relation to different warning systems and $t1$ scenarios

		best possible scenario (t1)	*average scenario (t1)*	*worst possible scenario (t1)*
w1	alarm bell	<3 mins	6 mins	>9 mins
w2	nondirective pre-recorded P.A.and/or inf.fire.warnings	<2 mins	4 mins	>6 mins
w3	live directive P.A +CCTV	<1min	2 mins	>3 mins

6.15 Speeds of response to an alarm bell on different occasions may vary between and within different types of occupancy across a wide range, although the range of times within a particular occupancy should be narrower. If the population of people in an occupancy, at the design stage and in post-occupancy evaluation checks, are scored on each of the each of Factors B to I in Table 1 on a scale of 1 (for the least efficient response) to 5 (for the most efficient response), the average rating across the range of factors can be entered into the following formula to establish an occupancy response efficiency weighting, *Weff* :

$$Weff = 5 \div \text{Average B - I}$$

6.16 Multiplying the baseline $t1$ b.p.s. for alternative warning systems, w1, w2 or w3, in a particular occupancy will give a measure of $t1$ which takes into account the various factors likely to delay people in starting to move:

$$t1 \text{ adjusted} = \text{w1, w2 or w3 } t1 \text{ b.p.s.} \times Weff$$

Occupancy	A Commun-ications	B Alertness	C Mobility	D Social Affiliation	E Role	F Position	G Commit-ment	H Focal Point	I Familiarity	J Popul-ation	K Visual Access	L Enclosure	M Comp-lexity
Hospitals	***	*	*	****	****	*	**	*	**	***	**	**	*
Residential Buildings	*	***	***	*	*	**	****	*	*****	*	****	*	*****
Nursing Homes	**	**	*	****	***	**	****	*	****	**	**	*	***
Hotels	**	***	****	****	***	**	****	*	*	**	**	**	****
Places of Assembly	***	*****	****	***	**	**	*	*****	**	***	****	***	****
Sports Stadia	*****	*****	*****	***	**	**	*	****	**	*****	***	*****	***
Shopping Complexes	****	*****	****	***	***	****	***	**	*	****	*	****	*
Shops	**	*****	****	***	***	***	***	***	**	***	**	**	***
Underground Stations	****	*****	****	****	***	*****	**	**	**	*****	*	***	*
Offices	**	*****	*****	****	*****	**	**	**	****	**	**	**	***

Coding scheme for asterisk ratings

A	B	C	D	E	F	G	H	I	J	K	L	M
no alarm	asleep	low	group	public	lying	high	none	unfamiliar	low	low	enclosed	complex
alarm bell	*	*	*	*		*	*	*	*	*	*	*
	**	**	**	**	sitting	**	**	**	**	**	**	**
non dir PA	***	***	***	***		***	***	***	***	***	***	***
	****	****	****	****	standing	****	****	****	****	****	****	****
	*****	*****	*****	*****		*****	*****	*****	*****	*****	*****	*****
directive P.A.	awake	high	alone	staff	moving	low	focussed	familiar	high	high	open	simple

Table 1 Illustrative matrix of factors influencing time to start to move (B-I) and direction of movement (I-M) in different occupancies

				t1 b.p.s. x W eff (mins)		
				w1 Alarm bell	w2 Non Dir P.A.	w3 Directive P.A.
Occupancy	Sum B-I	Avg B-I	W eff = 5 / Avg	3	2	1
Hospitals	16	2.0	2.5	8	5	3
Residential Buildings	20	2.5	2.0	6	4	2
Nursing Homes	21	2.6	1.9	6	4	2
Hotels	22	2.8	1.8	5	4	2
Places of Assembly	24	3.0	1.7	5	3	2
Sports Stadia	24	3.0	1.7	5	3	2
Shopping Complexes	25	3.1	1.6	5	3	2
Shops	26	3.3	1.5	5	3	2
Underground Stations	27	3.4	1.5	4	3	1
Offices	29	3.6	1.4	4	3	1

Table 3 Illustrative calculation of weighted t1 for different occupancies based on t1 b.p.s. x Weff (derived from Table 2)

(Include in an Appendix after further refinement and calibration?)